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THE SCIENTIFIC MONTHLY

OCTOBER, 1923

ANCIENT INSECTS; FOSSILS IN AMBER AND OTHER DEPOSITS

By Professor CHARLES T. BRUES

BUSSEY INSTITUTION, HARVARD UNIVERSITY

FRAIL creatures of the air and wholly destitute of a true bony skeleton, insects do not lend themselves so readily to fossilization as do many other organisms. The calcareous shells of molluscs and of several other types of invertebrate life, the siliceous skeletal elements of some other animals and plants and the bony internal skeleton of vertebrates are eminently suited for preservation, and it is only to be expected that these should be abundantly represented in sedimentary deposits, even of great age.

Nevertheless, Nature has conspired in several ways to make the task of the insect paleontologist easier and more profitable than the overworked entomologist might have dared to hope, had he remained wholly immersed in his job of sorting out the 10,000,000 living species of insects.

You may wonder why he has ever left such a permanently assured job even long enough to inquire into the possibilities of another, no matter how lucrative it might promise to be. You will understand, however, that it has been only when he wished to devote a few spare moments, stolen from his sabbatical leave, to some recreational, though kindred subject that these family skeletons have been exposed. Consequently, the vast opportunities for paleontological investigation have been seriously neglected by all but a few very inquisitive workers.

The fortunate circumstances that have aided the insect paleontologist are: First, the fact that the skeleton of the insect—if we may thus designate the wholly organic hard parts of the body—are entirely external and may thus be examined in the most minute detail in superficial view; and second, that the earlier insects, which have suffered more severely from the ravages of time, were larger

than most living species, some of really gigantic size; finally, many Tertiary insects are so wonderfully preserved that even the microscopic body-hairs and color can be made out on the surface of the finely laminated shale within which they are imbedded, while the specimens found in amber are still more nearly perfect.

Before discussing the Tertiary amber-fauna, it seems advisable to refer very briefly to its precursors, so far as they have been examined. No authentic insect remains are known from the Silurian or Devonian periods, although insect-like creatures probably existed at that time, but in the earlier deposits of the upper Carboniferous true winged insects appear. These early forms were of very generalized structure and have been designated as the order Paleodictyoptera. They were undoubtedly close to the ancestors of modern insects, as they possessed in combination the characteristics of several of the more primitive living orders. They must have been quite abundant, and over 100 species, representing more than 20 families, have so far been discovered; but the group did not persist beyond the upper Carboniferous.

By the middle portion of the upper Carboniferous the active evolution of the Paleodictyoptera had given rise to several more specialized groups, and these clearly forecast the differentiation of insects into some of the modern orders. Thus, the living Orthoptera were represented by the Protorthoptera, embodying certain characters of the common grasshopper or locust. The Protoblattoidea represented the proud ancestors of the despised domesticated cockroach. The Protodonata, some with a wing expanse of two feet, were glorified dragonflies, soaring through the luxuriant forests of the French coal-measures. Similarly, the modern may-flies were represented by generalized precursors. The higher living orders may also be traced through a common stem to the extinct order Megasecoptera. Finally, before the close of the Carboniferous, the first modern insects, true cockroaches, appeared.

Fossils of Carboniferous age are known from numerous localities in both Europe and North America, most abundantly in Commentry, in France, and at Mazon Creek, Illinois (Fig. 1).

The Permian introduces several additional modern orders, including true may-flies, stone-flies and mantids. Here appears also another group, the Protohemiptera, known from a single specimen, apparently intermediate between the Paleodictyoptera and the present-day order Hemiptera, one of the most highly specialized groups of insects, that appears in the upper Permian, at the same period that certain very primitive scorpion-flies are known to have existed.

The cockroaches dominated the Permian; numerous genera and

FIG. 1. Wings of a primitive Carboniferous cockroach, *Blattinopsiella pygmaea* Meunier, from Commentry. After Meunier.

species, some of them very closely allied, have been found, although only a comparatively small number of Permian insects have come to light. These are from scattered localities, particularly in Germany and the United States. At Cassville, West Virginia, are the remains of an abundant fauna from whence already 40 species of a single genus of cockroaches (Phyloblatta) have been described. Of this same Phyloblatta nearly 90 Carboniferous species have been recovered from various places in both hemispheres. Such a condition is very similar to that exhibited by some modern genera of insects which include many closely related species. As the fossil species must be classified almost entirely on the basis of wing-venation, it is of course possible and quite probable, indeed, that several related genera are here concerned, indistinguishable in the absence of the other body-parts.

Altogether, about 1,000 species of Paleozoic insects have been described.

Insects undoubtedly prospered throughout the Mesozoic era, although we have so far been able to learn comparatively little about them during the Triassic and Liassic.

The few Triassic insects known are referable to two orders, Coleoptera and Megaloptera, in addition to several orders previously mentioned. The Coleoptera, so abundant in the modern fauna, appear here for the first time, represented by beetles of quite ordinary appearance, which may in all probability be referable, at least in part, to living families.

The insect fauna of the Liassic period is somewhat better known and includes some true Orthoptera (locustids and crickets), Odonata (dragon-flies), Hemiptera, Homoptera, Neuroptera and Panorpatae (scorpion flies). Among these orders, several living families are represented.

The scorpion-flies are particularly interesting because they form the undoubted ancestral stem from which several of the highly specialized modern insects have been derived. Of the latter two appear before the end of the Liassic. They are the Phryganoidea (caddis-flies) and the Diptera (two-winged flies).

During the Jurassic period insects reached a very high state of specialization, and we have fortunately a tolerably good, although very incomplete picture of this fauna. The Lepidoptera (moths and butterflies) and the Hymenoptera (saw-flies, ants, wasps and bees) appear as two further offshoots from the aforementioned scorpion-flies. The Jurassic Hymenoptera include only the most primitive forms of the order, as the ants, wasps and bees did not appear till later. The Diptera, however, first seen as we have said in the Liassic, have progressed clearly towards their present stage of development. Jurassic insects are known mainly from the Bavarian lithographic limestone and from several localities in England. Further discoveries are undoubtedly destined to throw much light on the evolution of some of the recent orders and families.

The Cretaceous period is almost a blank from the entomologist's standpoint, although the existence of fossilized egg-masses, such as those of moths attached to leaves, and the presence of insect-galls on the leaves of plants show that the insects of that day had strikingly modern habits, especially in relation to the flowering plants which had reached a high stage of development.

In all, some 1,200 species of Mesozoic insects are known.

So far as our present knowledge goes, insects appear to burst forth in their full glory in the Tertiary as the culmination of a long evolution, the tedious nature of which I feel sure I have impressed upon you quite fully. Working onward from the Carboniferous they have thus paralleled in time quite closely the progress of the higher vertebrates and the Age of Mammals has become coincident with the Age of Insects. As a matter of fact these two groups of animals were already biologically linked in the Tertiary, as is evidenced by the occurrence of fossil fleas, bot-flies, mosquitoes and other blood-sucking flies.

About 7,000 species of Tertiary insects have been described, and there are very many others in collections awaiting study.

The Eocene we know must have supported an insect fauna very much like that of the present day. Although scarcely 300 Eocene

species have been described, they are sufficient to show that some modern genera are represented and that many of the fossil genera are quite similar to living ones. Nearly all the known species are from deposits in our own Rocky Mountain region which have not yet received extensive study.

Of all fossil insects, those of Oligocene age, imbedded in Baltic amber, are the most beautifully preserved, and by far the most satisfactory to study. Moreover, the supply of amber insects is almost unlimited. The finest collection extant, that of the Zoological Museum of the University of Königsberg, contains more than 100,000 specimens, and there are many smaller collections in various other places. As is well known, amber is the fossilized resin of certain coniferous trees, the Baltic amber derived, at least in great part, from *Pinus succinalis*, a fossil species related to our modern pines. After exuding from the tree, and while still in a viscous condition, many insects were caught on its surface, just as they are at the present day on the sticky mess of rosin and castor-oil, known as tangle foot, prepared for this specific purpose. Thus encased in the gradually hardened amber, the included insects are as perfectly preserved as though freshly mounted in Canada balsam, notwithstanding the lapse of several million years, or possibly of even 30 or 40 million years, according to some recent estimates. Some specimens are of course not so good as others. There were no professors of zoology handy to see that all specimens were properly dehydrated before mounting, that their appendages were neatly disposed in the balsam, and that air bubbles were carefully expelled by the gentle heat of an alcohol lamp before drying in a constant-temperature oven. Nevertheless, Nature has shown us what lasting preparations can be obtained without the use of a modern laboratory cluttered up with elaborate apparatus.

The most extensive amber deposits so far discovered occur along the Baltic coast of eastern Prussia, where their existence has been known for many centuries. At some places the deposits are worked for commercial purposes where they occur near the coast, and considerable quantities are also found cast up along the shore after storms. The individual masses vary greatly in size, but are usually small, ones weighing as much as ten pounds occasionally coming to light. The amber is always of decidedly yellow color, but varies greatly in shade, and also, which is more important from the paleontological standpoint, in transparency, for much of it is translucent or semi-opaque. The most probable assumption is that the present location of the Baltic amber beds is well removed from the original amber forests which occupied the more mountainous land to the north on the Scandinavian peninsula and in Finland, from

whence the relatively light amber was carried by streams and deposited along the lower Baltic levels.

Due to the manner in which the insects were caught by the exuding resin, there was a selection of particular kinds of insects. Naturally, no very large or powerful species were readily captured, and we find a conspicuous lack of those types which could readily free themselves from the resin. Also, since the resin accumulated upon the trunks of the trees, insects that regularly live a subterranean existence and those that normally remain upon the surface of the ground had little opportunity to come into contact with the fresh resin, and they do not generally occur in the amber. The forests were undoubtedly heavily shaded (Fig. 2), as are the coniferous forests of the present day, and sun-loving, flower-frequenting forms were consequently of infrequent occurrence. Thus we find that the bees, a group so abundant at the present time, are very poorly represented, known by only some fourteen recognizable species and forty specimens in all. The bees have been carefully examined by Cockerell, so that there can be no doubt of the scarcity of this group in amber. The same is true of the wasps, although to a lesser extent. These have not been extensively studied, and it is perhaps premature to suggest on the basis of the few published species and various others which I have examined that those groups whose present-day habits would lead them to such localities are better represented in amber.

On the other hand, small or weak-bodied insects are most abundantly represented, particularly those whose habits would lead them

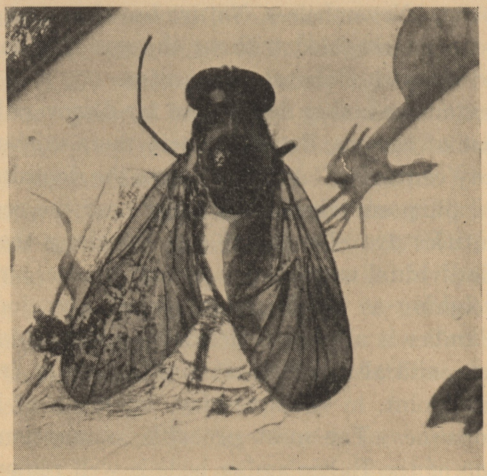

FIG. 2. Leptid fly, probably *Leptis fascinatoris* Meunier, in Baltic Amber. Magnified six diameters.

into the forests. This is perhaps best illustrated by the amber ant-fauna which was first carefully studied by Mayr and more recently and exhaustively by Wheeler. Thus, of the four subfamilies of ants, the most primitive, the Ponerinae, include at the present time mainly terrestrial or subterranean species, and although one tenth of the amber species belong to this group, less than one one-hundredth of the specimens are Ponerinae. We may very plausibly account for this discrepancy by the random trapping of a variety of stray individuals that ventured upon the tree-trunks. The subfamily Camponotinae includes at the present day many dominant, characteristically arboreal ants, and this group is very abundant in amber as the foraging habits of the workers regularly led them to the resin (Fig. 3). The great abundance of particular species is also nicely illustrated by the ants. Thus, two species of Iridomyrmex are known by 5,248 and 1,289 specimens, respectively, and the occurrence of as many as fifty workers of one species in a single block attests their abundance in the amber forests. Another ant, *Formica flori,* almost indistinguishable from the modern *Formica fusca* of Europe, is known from over 1,300 specimens.

Another group that is well represented is the Parasitic Hymenoptera (Figs. 4 and 12). These have not so far been extensively examined, but from the small number which I have so far been able to study, it is evident that the amber fauna is very rich in these insects, all rather small or weak-bodied and abundant at the present time in forests.

As has already been mentioned in connection with the ants, some species of insects have persisted from the Oligocene amber to the present day with so little change that the two forms at each end of the series might almost be considered as representatives of a

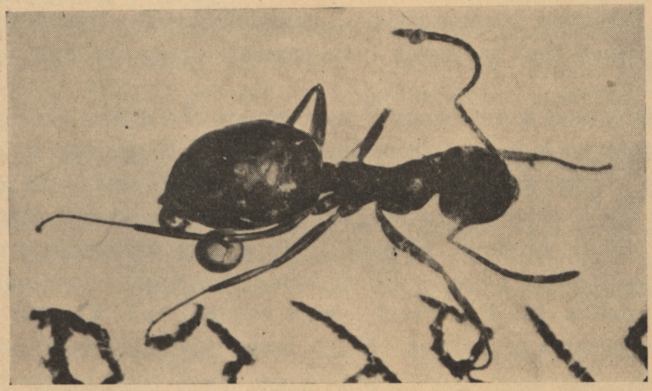

FIG. 3. A worker ant, Prenolepis sp., in Baltic Amber. Magnified 15 diameters.

FIG. 4. Parasitic Hymenopteron, Phygadeuon (*s. lat.*) *sp.* in Baltic Amber. Magnified 10 diameters.

single species. This is by no means true in general, however, and it is quite evident that evolution has not assumed the same gait in all cases. Certain dominant species, like the Formica referred to, have remained stationary, while other less abundant ones have no close relatives so far as we know in the modern fauna. Of course, very little is known of the living fauna of many parts of the world, and, as has already happened in several cases, we may expect a number of supposedly extinct Oligocene types to be found alive, if not flourishing. Nevertheless, it is interesting to note in connection with the questioned importance of natural selection in evolution that it is certain dominant types, presumably well adjusted to their environment, that have seen little change during the lapse of Tertiary time.

This is seen more clearly if we compare the extant genera with the extinct ones known from amber. For this purpose it is convenient to refer again to the ants, a recent group, and to the caddis-flies, a much older one, which, as we have already said, appeared in the middle Mesozoic (Liassic). In a very fine account of the amber caddis-flies (Fig. 5) Ulmer found that slightly less than half of the genera (46.4 per cent.) were extinct, and Wheeler found almost the same proportion (44 per cent.) of extinct genera among the ants. The close agreement in these two diverse groups is surprising, especially in view of the fact that my own investigation of the Parasitic Hymenoptera, although still incomplete, indicates a

FIG. 5. Caddis fly in Baltic Amber. Magnified six diameters.

far greater preponderance of living genera. It would be premature, therefore, to make a general statement on a numerical basis. If we compare, however, the living and extinct genera, for example, among the ants, we see that among twenty-four extant genera, known from amber, practically all are common, dominant present-day genera, whereas the closest living relatives of the nineteen extinct genera are so far as can be definitely determined far from dominant types. In other words, the dominant types are quite fixed and stable, whereas their less successful relatives are in an active state of evolution, due, it would appear, to the greater opportunities for natural selection.

Many close similarities between the habits and biological relationships of the amber insects and those of the present time may be inferred from a careful examination and comparison of the fossils.

From his taxonomic study of the caddis-flies, for example, Ulmer has been able to show that the terrain occupied by the forests of amber-producing pines was highly mountainous, as a large proportion of the species belong to recent genera known to develop in rushing mountain streams, while a far smaller number inhabit quiet water.

There are a number of insects of diverse sorts which at the present time make their abode only in the nests of ants. One entire family of beetles, the Paussidae, have such habits, and the occurrence of several genera of typical paussids in amber leaves no

FIG. 6. Worker ant of the common Baltic Amber species, *Lasius schiefferdeckeri* Mayr, with parasitic mite attached to the hind leg near the base of the tibia. Magnified 15 diameters.

doubt as to the association of these myrmecophiles with ants in the Oligocene. Still more striking is the occurrence of mites on the hind tibia of an amber species of Lasius (Fig. 6). Two worker ants each have a mite attached at exactly the same place. Modern ants of the genus Lasius are similarly infected by large mites of the genus Antennophorus which also attach themselves to the bodies of the worker ants in definite positions, usually on the head. Feeding upon the honey-dew secreted by aphids or plant-lice is a widespread habit among recent ants, and there exist in amber inclusions containing worker ants together with aphids, which they were undoubtedly attending in a similar way.

Many of the familiar tragedies were enacted under the shade of the trees of the amber forest precisely as we see them at the present day. In the block of amber shown in the accompanying photograph (Fig. 7, A) there is imbedded the empty shell of a Syrphid fly, lacking the head, wings and some of the legs. I have no doubt that it was the victim of a spider, of which many kinds are nicely preserved in other pieces of amber (Fig. 7, B).

As you will have noticed, the most minute details and even in some cases the pigmentation are recorded with great fidelity in the amber insects, but as we have already mentioned there are certain defects which render difficult the complete examination of nearly all specimens. In one like that shown in Fig. 8, one side is clearly visible in great detail through the transparent amber, but if we attempt to view it from the opposite side, it is seen that all detail is lost in a whitening of the medium due to water originally oc-

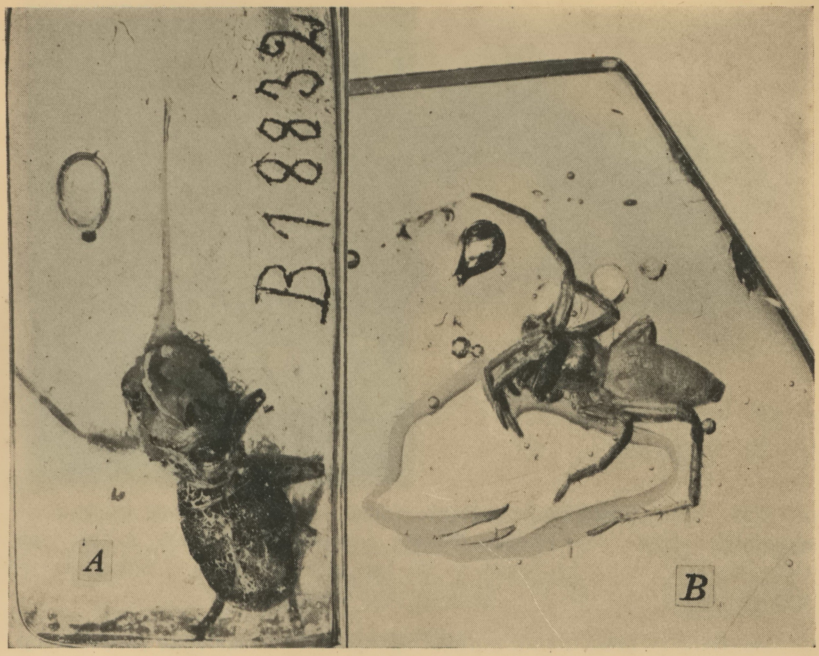

FIG. 7. The Spider and the Fly, in Baltic Amber. A, empty shell of a syrphid fly, with the head, wings and portions of some of the legs missing; B, Spider (Clubiona sp.). Both magnified about seven diameters.

cluded in the resin with the insect. Such defects are quite common. It will be noticed also that the tips of the antennae have been broken off, as they became dry and brittle before the resin had covered them. In other cases air has been included, present as bubbles. In still others, air surrounded parts of the body as a film, which on the hardening of the amber has allowed the matrix to shrink away from the body while still retaining on its surface a swollen and distorted impression of the real object. As the amber is highly refractive, the apparent form of such filmed parts is very deceptive. Other defects in the form of streaks and stream-like lines are often noticeable, as in the case of the spider shown previously. These are due to diffraction caused either by actual movements of the trapped insect through the surface film of the resin, or by shrinkage in the process of drying.

Small or minute insects are frequently preserved in almost perfect condition, due no doubt to the rapidity with which they were imbedded in the resin and to the greater readiness with which the air and water introduced with them was dissipated. Their beautiful preservation is well illustrated by the accompanying photographs of two fungus-gnats (Fig. 9), minute flies belonging to the order Diptera.

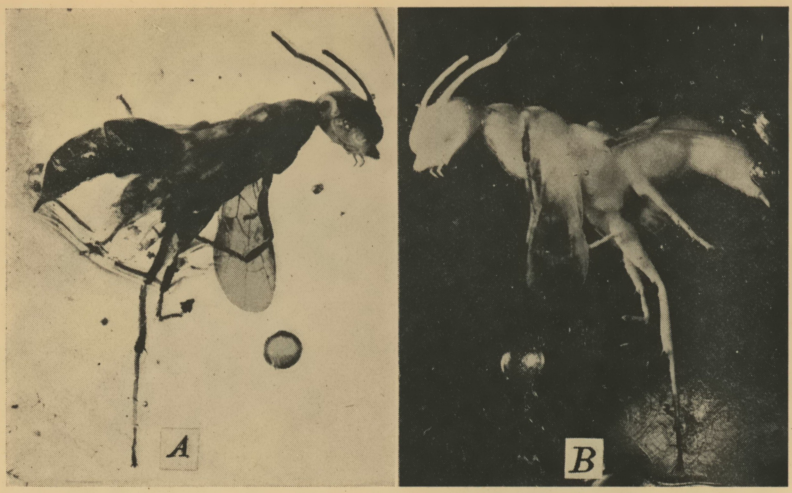

FIG. 8. Ampulicid Wasp in Baltic Amber. Two views of the same specimen from opposite sides to show the fine preservation of details on the right side (A) and their concealment on the left side (B) by a clouding due to moisture included at the time the insect was entrapped.

As already mentioned, several specimens often occur in the same lump of amber, which indicates positively not only that they were contemporaneous, but that all actually visited the particular tree from which the resin came. When different species are thus associated this enables us to relate them as to space and time, irrespective of the period during which amber may have been formed or the area over which the forests extended. The beetle shown in Fig.

FIG. 9. Two fungus-gnats (Mycetophilidae) in Baltic Amber. A. Sciara sp.; B. Macrocera sp.

FIG. 10. Small Cistelid beetle, embedded in the same block of amber with an ant, which is shown only indistinctly in the photograph.

10 is thus included in the same block with an ant that is not visible in the photograph, and the two insects in Fig. 12, B are both clearly shown in a single photograph.

Soft-bodied objects are also sometimes well preserved, like the succulent ant pupae here illustrated (Fig. 11, B). They belong to one of the very abundant amber ants, *Iridomyrmex geinitzi* Mayr.

A few other amber deposits are known from other parts of the world, and they have yielded also a number of insects, but nothing comparable to the rich and varied fauna of the Baltic amber. Sicilian amber, of middle Miocene age, is the most important of these. Quite recently a fauna of insects and some other Arthropods has been discovered in Burmese amber which is of great interest. These deposits may be Miocene, or perhaps older.

From a technical standpoint, it is disappointing to pass from amber fossils to petrified ones, of which several exceedingly rich deposits of Miocene age are known. The distinction is not so clear as might be taken from this statement, however. Amber insects are really highly metamorphosed, due to excessive dehydration and partial carbonization, as is evident if we remove the amber by means of a solvent and observe the hopelessly brittle and powdery nature of the inclusions. The "petrified" Miocene insect-remains are imbedded in finely laminated shales which readily split into layers of paper-like thinness, disclosing the insects flattened out and imbedded between adjacent layers. Thus enclosed in true rock, the remains still retain to some extent their organic composition, although highly carbonized (Fig. 13). Consequently the color pattern is often well preserved and even the metallic color of certain kinds, due in life to diffraction by the superficial layers of the chitinous body-wall, is still evident. Microscopic examination is possible and shows many details of structure.

These Miocene deposits are known mainly from three places, one

at Radoboj in Croatia (lower Miocene), another at Florissant, Colorado (probably middle Miocene), and the third at Oeningen, Bavaria (upper Miocene). Of these, the Florissant deposits have been most exhaustively studied, first by Scudder and more recently by Cockerell, who has not only intensively collected and examined this fauna himself, but who has also persuaded a few other entomologists to devote some attention to it. There are also extensive plant remains, mainly leaves, in the Florissant shales and these have been studied by Lesquereux and Cockerell.

The fossils are found in what was an old lake bed, where they were entombed in material formed by volcanic dust rapidly settling in the waters of the lake. As the chitinous exoskeleton of insects rapidly disintegrates in water, it seems probable that the cement-like character of the dust was an important factor in producing the large numbers of finely preserved specimens.

The general composition of the Florissant fauna is very much like that of the amber so far as its relations to modern insect life is concerned. However, on account of the less perfect preservation, it is more difficult to locate the species definitely in genera, and in the absence of many details there is a tendency to place doubtful species in modern genera from which some of them are probably distinct. With this in mind, it is likely that the smaller number of extinct genera at Florissant compared to Baltic amber is not so striking as would appear from an actual catalogue. Nevertheless, there are fewer extinct genera at Florissant than in the

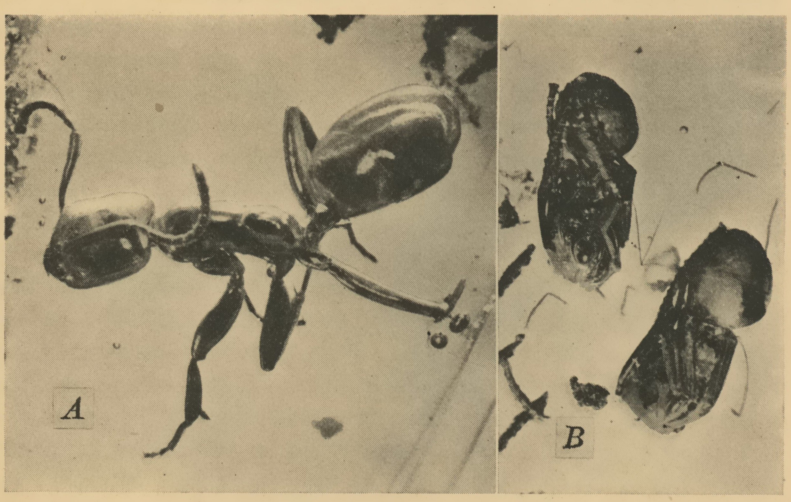

FIG. 11. An ant and ant-pupae in Baltic Amber. A. Worker of *Iridomyrmex oblongiceps* Wheeler; B. Pupae of workers of *Iridomyrmex geinitzi* Mayr.

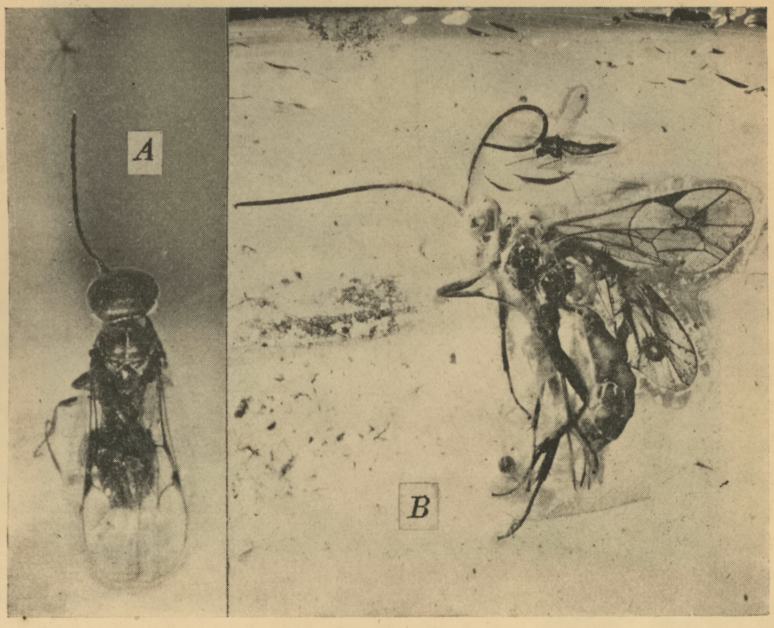

FIG. 12. Two species of Parasitic Hymenoptera in Baltic Amber. A, *Prodinapsis succinalis* Brues; B, Tryphon (s. lat.) sp. with a small midge in the amber just above.

amber, and the fauna in some groups at least has a typically North American aspect. This opinion has been expressed by Wickham, who has studied the beetles with great care, enumerating over 500 species. My own studies of the Parasitic Hymenoptera of Florissant based on 125 species, to which some have since been added by Cockerell, show the same small proportion of extinct genera, but do not suggest that the Florissant fauna appears to be actually ancestral to that of present-day North America.

As with the amber insects, many biological relations may be inferred or surmised from a study of the Florissant fossils. An interesting discovery is the finding of several species of Glossina, the well-known tsetse-flies, now confined to the African continent. The first was found by Scudder, who regarded it as a bot-fly, but its rediscovery together with three other species by Cockerell enabled him to determine without the slightest question that true tsetse-flies occurred in Colorado during the Miocene. As these flies now carry the trypanosomes of human sleeping sickness and of several fatal diseases of large mammals it needs no great reach of the imagination to suppose that these Miocene flies may have been instrumental in causing the extinction of certain large mammals formerly abundant in North America. As a matter of fact such a

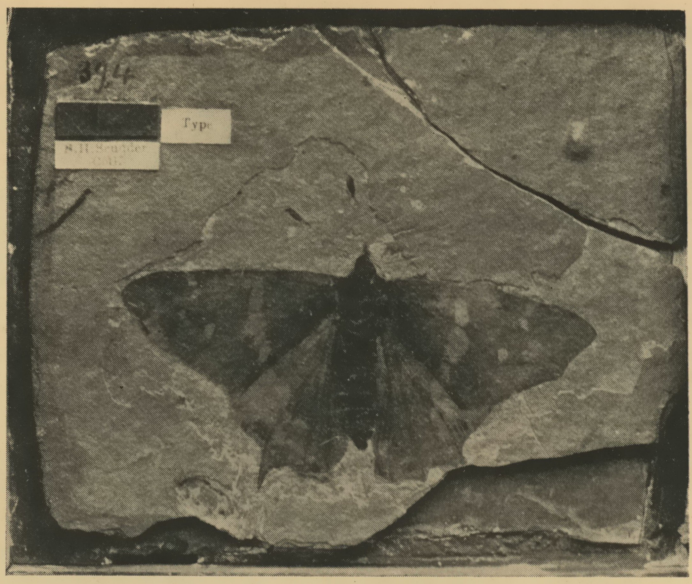

FIG. 13. Butterfly, *Prodryas persephone* Scudder, from the Miocene shales at Florissant, Colorado.

theory previously expressed by Osborn as a possible reason becomes a plausible one after the discovery of the tsetse-flies.

With so many opportunities in a little worked field it is surprising that the study of fossil insects has received such scant attention. Perhaps as the zoologist finds his researches into the activities of living animals increasingly hampered by the well-meaning anti-vivisectionists, he may later more profitably turn his attention to grinding sections of petrified insects, or to removing the amber from long extinct species with boiling turpentine. At any rate this occupation might furnish a harmless vent for his most vicious instincts.

THE ORIGINS OF THE CONCEPTION OF ISOTOPES[1]

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ONE of the most important consequences of the study of the chemistry of the products of radioactive change has been the discovery of isotopes and the interpretation in consequence of the Periodic Law in terms of modern views of atomic structure. It is one of the few fields in the vast borderland between physics and chemistry, overrun of recent years by an advancing swarm of mathematicians and physicists, armed with all sorts of new-fangled weapons, in which the invaders have found the chemist already in possession. The broad highways they have hewn thereto are already dusty with the tread of pilgrims, and are being watered by the tears of candidates for "Honors." But the somewhat intricate by-ways through which the chemist first found his way into this virgin territory, and the views on the road before it was in sight, may still preserve something of their pristine interest.

The word *isotope* signifies "the same place," in allusion to isotopes occupying the same place in the Periodic Table. Before this word of theoretical meaning was coined, isotopes were experimentally well known as elements non-separable by chemical methods and completely identical in their whole chemical character. The analysis of the constituents of matter, to which we were born and brought up to regard as the most searching and fundamental, is an analysis by means of its chemical properties. Although, later, a new and even more powerful method, spectroscopic analysis, was developed, it merely dotted the *i*'s and crossed the *t*'s of chemical analysis, filled in a few vacant places in the Periodic Law, and handed over the newcomers to the chemist to classify along with the rest of the eighty or so "foundation stones" of which he supposed the material universe to be built up. Then, with the close of the last century, another new method, radioactive analysis, was developed, which is applicable of course only to the radio-elements—that is, to the elements uranium and thorium and the thirty-four, as we now know, successive unstable products of their spontaneous disintegration. Each of these possesses a definite radioactive character;

[1] Address delivered before the Royal Institution of Great Britain, May 4, 1923.

it is produced from one and changes into another element, and, in both changes, rays characteristic of the two substances are expelled, which are as fine a hall-mark of their identity as any of the "tests" of chemical analysis. But radioactive character, unlike spectroscopic character, is completely independent of chemical character. The latter might be called "existence properties," whereas the radioactive character is that attending the explosion of the atom which terminates the existence of the element as such. It provided the necessary independent method of analysis capable for the first time of distinguishing between elements identical chemically and occupying the same place in the Periodic Table—*i.e.*, between isotopes.

The Earlier Chapter of Radio-Chemistry

Not a hint of this, however, was afforded by the earlier chapter of radio-chemistry. On the contrary no development could appear more normal. Just as rubidium, thallium, etc., were detected by the spectroscope before anything of their chemistry was known, so radium was detected in pitchblende by its radioactivity in concentration thousands of times less than is necessary to show a single line of its spectrum. But with more concentrated preparations a new spectrum *was* discovered, and then a new element, which was found to possess a chemical character entirely new and sufficing for its separation in the pure state from all other elements. As in the case of the elements discovered by the spectroscope, radium was found to occupy a place, hitherto vacant, in the Periodic Table. But as it happened radium is exceptional in this. Its chemical character was quite normal, and indeed could have been largely predicted beforehand for the missing element occupying this place. The development of the subject showed it to be but one of some thirty-four radio-elements formed from uranium and thorium. But there are not thirty-four vacant places in the Periodic Table to accommodate them.

Meta-Elements

So far as I am aware, there is no anticipation, prior to the systematic study of the chemistry of the radio-elements, of the idea that there may exist different elements with absolutely identical chemical character. Sir William Crookes, it is true, once thought, though the idea has not survived more extended examination, that the properties of the elements, as we know them, might be a mean value, and that the individual atoms composing the element might differ in weight and chemical character continuously on either side of this mean. If so, more refined methods might serve to resolve the element into a collection of what he termed "Meta-Elements,"

possessing the main character of the original, but differing from one another to a slight extent. Misled by the phosphorescence spectra, which are now known to be characteristic of mixtures rather than chemically homogeneous substances, he thought at one time that he had been successful in so resolving yttrium. But the present idea that elements may exist, absolutely the same in chemical nature and yet absolutely different in other properties, such as radioactivity and atomic weight, is totally distinct from this.

The Experimental Method that First revealed Isotopes

I venture to think that no more elegant extension of our methods of gaining new knowledge has ever been obtained than that which, in due course, was to reveal the existence of isotopes. The original observations, upon which the theory of atomic disintegration was first founded, were that thorium is continuously producing a new radioactive substance, thorium X, separable from it by precipitation with ammonia, but not with other precipitants, and, after separation, continuously re-forming again. The thorium X was short-lived, and changed again into a gas, the thorium emanation, for which the name thoron has recently been proposed, which was even shorter-lived and changed again to a solid, the "excited activity," now known as the active deposit, which again went through further changes. The rays resulted from these successive changes, α-rays in the first, and α-, β- and γ-rays in the last changes. Below is the first part of the thorium disintegration series as it appeared to Sir Ernest Rutherford and myself in 1903:

$$\text{Thorium} \xrightarrow{\alpha} \text{Thorium X} \xrightarrow{\alpha} \text{Thoron} \xrightarrow{\alpha} \text{etc.}$$

In 1905 Sir William Ramsay and O. Hahn were engaged in extracting radium from thorianite, a new Ceylon mineral containing both uranium and thorium in important quantities. The radium was separated with the barium, and the chlorides fractionated in the usual way. They found a new radio-element to be present, and to be separated from the radium with the barium. It proved to be the direct parent of thorium X, and intermediate in the series between the latter and thorium, and they called it radiothorium. In spite of this easy and apparently straightforward separation, the experience of a number of chemists showed that something remained to be explained, for it was found to be difficult to the verge of impossibility to separate radiothorium from thorium. Ramsay and Hahn had in fact "separated" isotopes in 1905, for radiothorium and thorium are isotopes. Yet further work has shown the two to be so alike that no separation by chemical means is possible!

Then in 1907, along with the radium which had been separated from thorianite, Hahn discovered another new radio-element, mesothorium, the direct parent of radiothorium and intermediate between it and thorium. In the next year he showed that mesothorium consists of two successive products—the first, the direct product of thorium, mesothorium 1, being practically rayless and generating a short-lived product, mesothorium 2, giving powerful β- and γ-rays.

This resolved the mystery, and one can not do better than to quote the words of McCoy and Ross (*J. Amer. Chem. Soc.*, 1907, 29, 1709):

"Our experiments strongly indicate that radiothorium is entirely inseparable from thorium by chemical processes. . . . The isolation of radiothorium from thorianite and from pure thorium nitrate . . . may have been accomplished by the separation of mesothorium, which in time changed spontaneously into radiothorium."

Thus the radiothorium separated from the mineral thorianite by Ramsay and Hahn was not the radiothorium *in the mineral*, but that subsequently produced from the easily separated mesothorium, after it had been removed from the thorium. If they had fractionated the radium-mesothorium-barium mixture at once they would not have discovered radiothorium. The lapse of time after the separation of the mesothorium is essential. Nowadays many non-separable radioelements are, like radiothorium, "grown" from their separable parents. Thus radium D, an isotope of lead, is grown from the radium emanation (radon) although it can not be separated from the mineral, which always contains lead in quantity.

The first part of the thorium series now runs:[2]

$$\underset{2.10^{10}\text{ years}}{\text{Thorium}} \xrightarrow{\alpha} \underset{9.67\text{ years}}{\text{Mesothorium 1}} \rightarrow \underset{8.9\text{ hours}}{\text{Mesothorium 2}} \xrightarrow{\beta}$$

$$\underset{2.91\text{ years}}{\text{Radiothorium}} \xrightarrow{\alpha} \underset{5.25\text{ days}}{\text{Thorium X}} \xrightarrow{\alpha} \underset{78\text{ seconds}}{\text{Emanation}} \xrightarrow{\alpha} \text{etc.}$$

In this series thorium and radiothorium and mesothorium and thorium X are two pairs of isotopes. If we represent the successive products by balls of different colors to indicate their chemical character, isotopes being of the same color, chemical analysis will sort the balls into their different colors, and the lapse of time will cause some of the colors to change. The ball representing mesothorium will in time turn into that representing radiothorium, so

[2] The periods shown in the second line are the periods of average life of the successive products. These are 1.443 times the period required for one half of the element to change.

that the latter, before indistinguishable from thorium, becomes known as a separate individual.

The Isotopes of Uranium

It will be noted that the method of separating isotopes depends upon their being alternate rather than successive in the series. If radiothorium had been the direct product of thorium, the two would never have been separated to this day. The changes of chemical character are, as we shall later see, intimately connected with the electric charges on the α- and β-particles expelled. For successive products to have the same character no rays, or at least no charged particles, must be expelled. It is always as well—and no subject illustrates the point better than that of isotopes—to reflect not only upon what our methods are able to reveal, but also upon what they can not reveal.

At first it seemed as if uranium itself was a case of successive isotopes. Boltwood in 1908 proved from his study of the relative activities of the successive products giving α-rays in minerals, that whereas all of them, except uranium, gave off only one α-particle per atom disintegrating, uranium gave off two. By direct observation with the scintillation method it was proved that the two α-particles from uranium are *not* simultaneously expelled, and later it was shown that they possess different velocities. If the slower comes from uranium itself (uranium I), the period of which is known to be 6.10^9 years, the swifter must come from the isotope (uranium II), and its period must be some three million years. This is an example of isotopes being revealed by difference of radioactive nature simply, though no other evidence of their separate existences is available. Owing to the long periods of the α-ray giving members of the early part of the uranium series, it has been much more difficult to unravel than the thorium series. As a result of researches too numerous to detail, it has been concluded that the main series is almost entirely analogous to the thorium series, and runs:

$$\underset{6.10^9\text{ years}}{\text{Uranium I}} \xrightarrow{\alpha} \underset{35.5\text{ days}}{\text{Uranium X}_1} \xrightarrow{\beta} \underset{1.65\text{ minutes}}{\text{Uranium X}_2} \xrightarrow{\beta}$$

$$\underset{3.10^6\text{ years}}{\text{Uranium II}} \xrightarrow{\alpha} \underset{10^5\text{ years}}{\text{Ionium}} \xrightarrow{\alpha} \underset{2440\text{ years}}{\text{Radium}} \xrightarrow{\alpha} \underset{5.55\text{ days}}{\text{Radon}} \xrightarrow{\alpha} \text{etc.}$$

Though two short-lived products probably intervene between the two uraniums, analogous to the two mesothoriums between thorium and radiothorium, the relation of their period to that of their product, uranium II, is so hopelessly unfavorable that there is no hope

of ever being able to put the separate existence of uranium II into evidence in the same way as was done for radiothorium. For all *practical* purposes the two uraniums are as non-separable by this method as if they were actually successive products. I spent many years, before this part of the series was at all well known, looking for the product of uranium X, and separated this constituent from 50 kilograms of uranium nitrate repeatedly in the attempt. I was looking for a growth of α-rays concomitantly with the decay of the β-rays of the uranium X. If the product had been ionium, as at first thought ($U\ I \xrightarrow{\alpha} U\ II \xrightarrow{\alpha} U\ X \xrightarrow{\beta} Io \xrightarrow{\alpha}$), it should have been just possible to detect it. But since it is the thirty times longer-lived uranium II, the attempt is hopeless, especially as uranium X and ionium are isotopes, and therefore the uranium X separated must always possess a certain initial α-activity due to ionium.

The Absolute Chemical Identity of Isotopes and its Implications

The years 1908–1910 were productive of many prolonged and serious efforts to separate isotopes by chemical means. In 1908 Boltwood discovered ionium, and showed that it resembled thorium. Keetman, who with Marckwald discovered ionium independently, tried twelve good methods, all known to be effective, in the purification of thorium in the attempt to separate the ionium from thorium, completely without success. Auer von Welsbach, on a technical scale, separated the ionium and thorium from 30 tons of pitchblende, and tried fresh methods in the hope of separating them, but failed. It was with this preparation that Exner and Haschek tried without success to find the ionium spectrum, and Russell and Rossi confirmed their result, that the spectrum was that of pure thorium. When later I had determined beyond doubt, from measurements of the rate of growth of radium from uranium, that the period of ionium was 100,000 years, and that Welsbach's preparation must have been approximately 30 per cent. ionium and 70 per cent. thorium by weight, it followed that the spectra of isotopes must, like their chemical character, also be identical. The difference, if any exists, is almost beyond the limit of detection by the most powerful methods.

Similarly, the chemical identity of radium D and lead was established as a consequence of very prolonged and refined chemical examination. Paneth and Hevesy established upon this their well-known method of using radioactive isotopes as indicators for elements in too small quantity to be dealt with except by such methods. On the principle that wherever the radioactive element

is there will its inactive isotope be also, provided that they have once been properly mixed, many difficult or uncertain chemical analyses may be converted into simple radioactive ones.

In 1909 Strömholm and Svedberg made what was probably the first attempt to fit a part of the disintegration series into the Periodic Table, and although the effort in itself was in an important respect erroneous, in their paper is to be found the first anticipation that the chemical non-separability found for certain pairs and groups of radio-elements may also apply to the non-radioactive elements. Remarking on the fact that there are three parallel and independent radioactive series, they suppose this to proceed down through the Periodic Table, "but that always the three elements of the different genetic series, which thus together occupy one place in the periodic system, are so alike that they always occur together, and also have not been able to be appreciably separated in the laboratory." They point out also this idea would explain the exceptions to the periodic system "if the elements of the scheme were mixtures of several homogeneous elements of similar but not completely identical atomic weight."

In the next year I arrived independently, and without in the least postulating any continuance of the genetic series beyond the radio-elements, at a similar view. Marckwald and I found independently that mesothorium I was chemically similar to radium, a fact undoubtedly known to Hahn and those engaged in the technical extraction of mesothorium, but kept secret. It was known from some work of Boltwood that precipitating barium sulphate in a solution containing mesothorium removes it, but it was thought that the action of the barium sulphate was similar to that in removing uranium X, for which it had long been used—namely, a simple adsorption. I was surprised to find it absolutely different. The removal of the barium from the mesothorium, as from radium, could only be accomplished by the fractional crystallization of the chlorides. In this fractionation the radium and mesothorium remained together and behaved as a single element. Within the limit of error of the most careful radioactive measurements, there was no change in the relative proportion of the two elements at the end of the process, from that in which they exist in the original mineral. Chemistry has many cases of elements similar in chemical character, but nothing approaching this. For we know, beforehand, that we are dealing with a mixture of two substances, and can estimate accurately the proportion of each individual. Yet to all chemical operations they behave as a single substance. The differences of atomic weight are considerable, two units in the cases of mesothorium and radium, and of ionium and thorium, and four units

in that of radiothorium and thorium. It was certain that if isotopes existed in the case of the ordinary chemical elements, the absence of a second radioactive nature independent of the chemical nature would make it impossible for them to have been recognized. Hence the implication followed that any supposed element may be a mixture of several chemical identities of different atomic weight, and any atomic weight might be merely a mean number (Ann. Reports, Chem. Soc., 1910, 286). There is an element of tragedy in this. The life-time labors of the chemists who, since the time of Stas, have devoted themselves to the exact determination of atomic weight, appear to have as little theoretical interest now, as if you sought to determine the average weight of a collection of beer bottles, all exactly alike, but not all quite full.

The Radio-Elements and the Periodic Law

The years from 1911–1913 were crowded with important advances, and to do the exact history justice would take an undue share of the available time. In 1911 the chemistry of most of the α-ray giving members were sufficiently known for it to be seen that the expulsion of the α-particle caused the element expelling it to move from the place it occupied in the Periodic Table to the next place but one to it in the direction of diminishing mass.

At this time the chemistry of the post-emanation members had scarcely been studied, though von Lerch, from electrochemical researches, had put forward the rule that the successive products are each electrochemically "nobler" than the last, a rule which describes well enough the electrochemical behavior of the first three —the A to C members, as they are called. Then as a result of the experiments of Schrader and Russell, it was found that their volatility was much affected by chemical treatment and by the atmosphere in which they were volatilized. Thus, in hydrogen, radium C volatilizes at as low a temperature as 360° C., though, in air, a temperature of 1200° C. is necessary. This clearly indicated the possibility that even these excessively ephemeral elements have a definite chemical character. Hevesy showed, by electrochemical methods, that the three B-members are identical in properties among themselves, and also the three C-members.

But the work, which, more than anything else, served to reveal as in a flash the simple and sweeping generalization which covers the evolution of the radioactive elements was that of A. Fleck in my laboratory in Glasgow. He studied the chemistry of the various members, still uncharacterized, from the definite point of view of ascertaining to which element each most closely approximated in chemical character, and then whether it was separable from that

element or not. In addition to confirming more rigorously many conclusions already reached, he proved that mesothorium 2 was non-separable from actinium, the three B-members from lead, like radium D, and the three C-members and radium E from bismuth.

Hevesy and Russell—the first with regard to the valency of the radio-elements and the second with regard to the positions they occupy in the Periodic Table—published early in 1913 statements of the full law underlying radioactive evolution, but only in part correct. Within a month K. Fajans in Carlsruhe published the scheme correct and complete, including the complicated branchings that occur at the C-members. In a paper, amplifying and amending Russell's scheme, I arrived independently at the same place as Fajans. Each α-ray expelled causes a shift of two places in the Periodic Table in the direction of diminishing mass, and each β-ray a shift of one place in the opposite direction. In its present form the scheme is shown in the figure. The chief uncertainty remaining is whether the actinium branch starts from uranium II, as shown in the figure for convenience, or from uranium I, or even from a third independent isotope of uranium. So that the atomic weights shown for the actinium series are purely provisional.

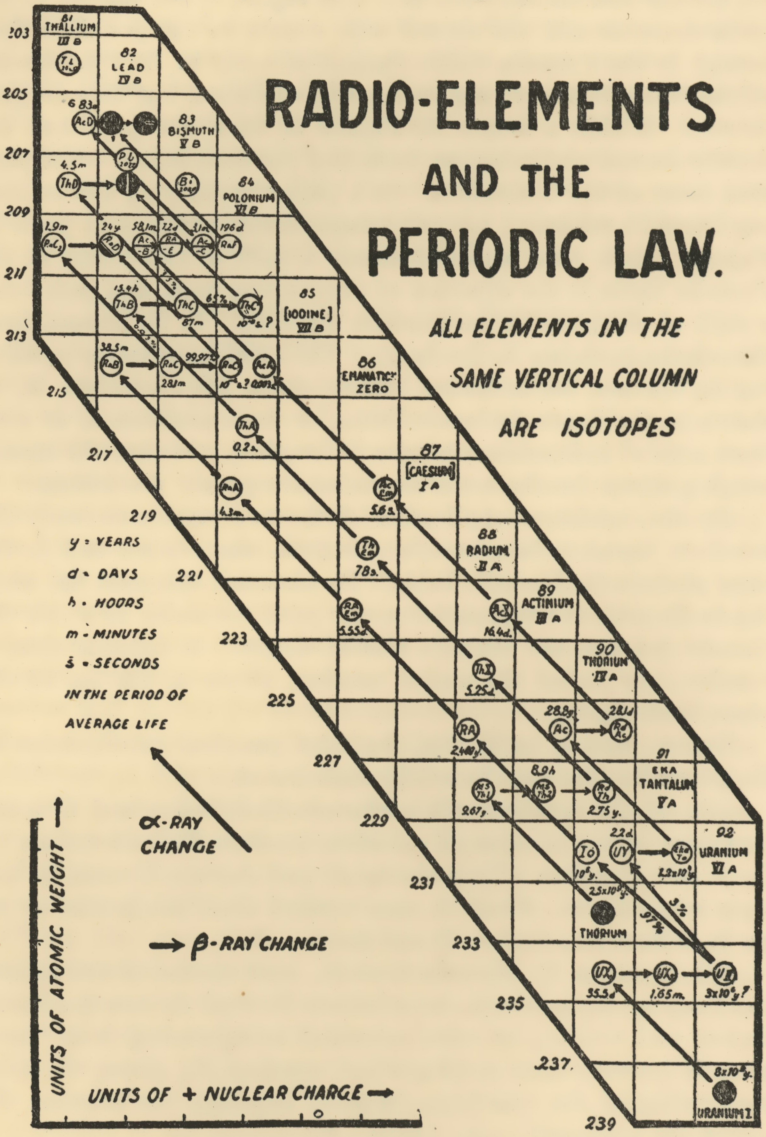
By the consistent application of the two rules mentioned the members found to be non-separable from one another fall in the same place in the Periodic Table. The chemical character has nothing to do with the radioactivity, nor with the series to which the element belongs, nor with its atomic weight. It depends upon a number, now called the atomic number, shown at the top of the place in the figure.

Before passing on to this, the chief practical consequences of the generalization may be briefly enumerated.

(1) Of the members still uncharacterized, the A and C′ members must be the isotopes of polonium (radium F), and radium C_2 (now called radium C″), actinium D and thorium D must be isotopes of thallium. Fleck at once verified these predictions as regards radium A, actinium D and thorium D.

(2) Uranium X, like mesothorium, must consist of two successive β-ray giving products, intermediate between the two uraniums. Fajans and Gohring at once succeeded in separating from "uranium X" a very short-lived product, uranium X_2, giving the more penetrating of the two types of β-ray expelled, the uranium X_1 giving the less penetrating β-rays.

(3) The parent of actinium in the IIIrd family must be an isotope of radium, if actinium is formed in a β-ray change—a conclusion I at once experimentally disproved—*or* it must be an isotope of uranium X_2, in the Vth family, if actinium is formed in an α-ray


RADIO-ELEMENTS
AND THE
PERIODIC LAW.
ALL ELEMENTS IN THE
SAME VERTICAL COLUMN
ARE ISOTOPES
y = YEARS
d = DAYS
h = HOORS
m = MINUTES
s = SECONDS
IN THE PERIOD OF
AVERAGE LIFE
α-RAY
CHANGE
β-RAY CHANGE
UNITS OF ATOMIC WEIGHT
UNITS OF + NUCLEAR CHARGE
81 THALLIUM III B
82 LEAD IV B
83 BISMUTH V B
84 POLONIUM VI B
85 [IODINE] VII B
86 EMANATION ZERO
87 [CAESIUM] I A
88 RADIUM II A
89 ACTINIUM III A
90 THORIUM IV A
91 EKA TANTALUM V A
92 URANIUM VI A
THORIUM
URANIUM I
203
205
207
209
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213
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change. This was proved by Cranston and myself, and the name "eka-tantalum" given to the new element, and by Hahn and Meitner, who named it protoactinium. It is linked to uranium through uranium Y, a branch member discovered by Antonoff in 1911, and suspected to be in the actinium series.

Protoactinium, to give it Hahn and Meitner's name, has been shown by them to give α-rays, and to be chemically so like tantalum that hitherto it has not been separated from it. Its period is about 17,000 years, and from this it may be calculated that there is about one fifth as much of it by weight in minerals as there is of radium. This may be sufficient to enable it to be isolated and for its spectrum, atomic weight and chemical character to be ascertained. The branch series runs:

$$\underset{\text{VI}}{\text{U}} \xrightarrow{\alpha} \underset{\text{IV}}{\text{UY}} \xrightarrow{\beta} \underset{\text{V}}{\text{Pa}} \xrightarrow{\alpha} \underset{\text{III}}{\text{Ac}} \xrightarrow{\alpha} \underset{\text{IV}}{\text{RaAc}} \xrightarrow{\alpha} \underset{\text{II}}{\text{AcX}} \xrightarrow{} \underset{\text{O}}{\text{An}} \xrightarrow{\alpha} \text{etc.}$$

in which the figures in the second line refer to the family in the Periodic Table to which the element belongs.

(4) All the ultimate products in all branches are isotopes of lead. The atomic weight of the two products of thorium are both 208, and of the major branch of uranium 206. As is well known this had only to be tested to be proved correct. The atomic weight of the lead from the purest thorium minerals is as high as 207.9, and of that from the purest uranium minerals 206. The spectra of these isotopes, but for the possible infinitesimal difference already alluded to, are identical. But the densities are proportional to their atomic weights. This was a very simple prediction I made, before testing it, from the theoretical views about to be dealt with.

The Theoretical Interpretation of Isotopes

The results on the theoretical side were no less definite and important, and isotopes found a ready explanation on the nuclear theory of atomic structure put forward in a tentative form by Rutherford in 1911. This theory accounted for the large angles through which occasional α-particles were deflected in their passage through atoms, by the existence of a very minute highly charged nucleus at the centre of the atom, the rest of the atom being occupied by separate charges of opposite sign equal in number to the nuclear charge. For such an atom scattering should be proportional to the square of the nuclear charge. Experiment showed that scattering was approximately proportional to the square of the atomic weight. So that it looked as if, as in the α-particle itself, there existed one unit of nuclear charge to each two units of atomic weight. This would make the nuclear charge of uranium, of atomic weight about 240, 120 +.

Since the α-particle carries two positive charges and the β-particle one negative, the obvious inference from the figure is that the successive places in the Periodic Table correspond with unit difference in the intra-atomic charge. This view, and also that each unit of charge corresponded to two units of mass, had been suggested independently by van der Broek in 1911. At first he tried to stretch the Periodic Table to make it accommodate 120 places. But, in 1913, he pointed out that the experimental results for scattering were completely in accord with his own view (that the number of the place is the same as the intra-atomic charge), *on the existing Periodic Table,* which accommodates only some 90 elements. It would not be inconsistent with his other view (that the nuclei of the heavy elements are made up of helium nuclei) if there were electrons in the nucleus as well as in the outside shell. Thus uranium in the 90th place would have to have, in addition to the 60 helium nuclei in its nucleus to account for its weight, 30 electrons, to account for its charge of 90 +.

The existence of electrons as well as positive charges in the atomic nucleus was also postulated by Bohr to explain the emission of β-*rays,* for on his theory the electrons in the external shell form a stable configuration and could only be dislodged by the expenditure of work.

The Periodic Law generalization practically settled this question. β-ray changes are no less transmutational than α-ray changes, and are sharply to be distinguished from the numerous processes, such as friction, chemical change, action of ultra-violet light and incandescence, during which electrons are detached from atoms. The effect on the chemical character produced by the expulsion of one α-particle is exactly undone by the expulsion of two β-particles, and the product becomes isotopic with the original parent. This means that both α- and β-particles must be expelled from the nucleus, and that isotopes are elements the atoms of which have the same *nett* nuclear charge—*i.e.,* the same excess number of positive over negative charges in the nucleus, but different numbers of positives and negatives reckoned separately. For such systems the electronic shell would be identical, and so the identity of the chemical and spectroscopic character is explained. Also the atomic volume is the same—that is, the density must be proportional to the atomic weight.

We were able to get an interesting confirmation of this view. In the change of uranium X_1 to uranium II two electrons are lost as β-rays. In the oxidation of a uranous salt to a uranic or uranyl salt two electrons are also lost. If these come from the same region of the atom as the β-particles, then uranous salts, so long as their

valency does not change, should be like uranium X_1, chemically non-separable from thorium. Fleck, trying this, found great similarity in chemical properties between uranous salts and thorium, but not identity. He was able to separate them by chemical methods without changing the valency of the uranous salt.

The great merit of the nuclear atom from the chemist's point of view was that it afforded for the first time a clear picture of the difference between a chemical and a transmutational (or radioactive) change. The latter occur in the nucleus and are irreversible. The external shell accommodates itself instantly to the change of the nucleus. But any change suffered by the external shell (chemical change) has no effect on the nucleus, which always acts so as to make the external shell conform to one most stable configuration.

The atom is an *imperium in imperio,* and like most such systems is very conservative and resistant to change. The electrons in the shell, that govern almost all the atomic properties, except mass and radioactivity, are in turn but the bureaucratic instruments of the real government, which is the intensely charged central nucleus. The transmutation of atoms, as of social systems, is alike impossible because the apparent government is not the real government. Rutherford's experiments, on the bombardment of atoms by α-particles, show that only about one out of a hundred thousand of the latter in passing through hydrogen ever hit a hydrogen nucleus, and the proportion of hits to misses is something like one in one thousand millions. In politics, contrasting the number of missiles hurled with the results achieved, the shooting seems even worse. It is only when the atomic or social systems break up or break down that we learn even of the existence of their real internal constitution.

PETRUS BONUS AND SUPPOSED CHEMICAL FORGERIES

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STUDENTS who have followed the history of early chemistry will remember that the results of critical research during the past half century have thrown grave doubts upon the authenticity of a number of medieval authorities on chemistry or alchemy.[1] Notable among these are alchemical treatises ascribed to Thomas Aquinas, prominent ecclesiastic who died in 1274 A. D., and to whom Professor Karl Schmieder in his "Geschichte der Alchemie" (1832) attributes six treatises on alchemy, and cites as many more titles on the authority of Borellus; Albertus Magnus (died 1282) to whom Schmieder attributes ten treatises on chemistry of which, one only, on minerals, is now accepted as genuine; Roger Bacon (died 1292), for whom Schmieder lists fifteen articles, nearly all of which are considered fraudulent. Two other of the principal authorities of the alchemists were Raymond Lully and Arnald of Villanova. Schmieder lists twenty-five titles to Lully and twenty to Arnald. Yet B. Haureau, the scholarly biographer of Lully and Arnald, presents good reasons for believing that all attributed to Lully are forgeries of later date, and for doubting that any alchemical writings attributed to Arnald are authentic, and other modern critics have come to the same conclusion. Lullus died in 1315 and Arnald about 1312. Generally speaking, the disbelief in the authenticity of these treatises has come from internal evidence presented by the treatises themselves, either in allusions made to persons or events later than the twelfth or early thirteenth centuries, or from discrepancies in subject-matter or style of writing between these treatises and the unquestioned writings of these prominent scholars.

The fourteenth and fifteenth centuries were periods when alchemical literature was very generally issued anonymously or under false names. Reason for this existed in the attitude of church and civil authorities toward alchemists. As these were generally believed to be counterfeiters and makers of false gold and silver, and sometimes to be in league with evil spirits, many edicts were issued against practicing alchemy and even the possession of alchemical

[1] Compare the writer's article, "Falsifications in the history of early chemistry," SCIENTIFIC MONTHLY, XIV, p. 560.

books and apparatus. A common custom, therefore, of those who nevertheless wrote on alchemy was to credit their works to some past author of established reputation in some natural science, and evidently these manuscripts would have a greater circulation if this author were a person of distinction.

By the beginning of the 16th century, when book-printing became general, great numbers of these manuscripts were printed, either separately or in collections, and here again unscrupulous publishers sometimes attached prominent names as authors of anonymous manuscripts. It can readily be understood that this flood of printed works presented serious problems as to dates of writing and as to authorship, which the scholarship of the period was in no position to solve. With some sporadic doubts and exceptions, these manuscripts were accepted at their alleged valuation, and only on the basis of much later critical comparisons were other conclusions often adopted.

Earlier historians of chemistry, Lenglet du Fresnoy, Gmelin, Schmieder, Hoefer and Kopp accepted as genuine the writings on alchemy attributed to Albertus Magnus, Roger Bacon, Lully and Arnald of Villanova, and it is indeed mainly from considerations which have developed during the past half century that the present disbelief in their authenticity has arisen. This conviction has been the result of more accurate knowledge of the life and works of the men, from internal evidence contained in the treatises in question, and from comparisons of the subject matter and style in the works of acknowledged authenticity with the works suspected of interpolation. Any direct evidence from the period of the writing of these suspected writings is in general wanting. Under these conditions, importance attaches to certain circumstantial evidence from a treatise written by an Italian called Petrus Bonus, who wrote an elaborate treatise of some 85,000 or more words on the philosophy of alchemy, in which he treats exhaustively of the reasons for and against the truth of the art and of various theories advanced or maintained in the science. In this lengthy discussion he depends upon the opinions and statements of previous writers, and cites his many authorities frequently and conscientiously. The work bears the date of 1330, and upon the accuracy of this date its value as evidence here depends.

In the text following the preface and just preceding Chapter I of the twenty-five chapters, it is stated (translated):

> Here begins a treatise by Master Petrus Bonus, the Lombard of Ferrara, natural Philosopher, introductory to the Art of Alchemy, composed in the year 1330 from the birth of our Lord Jesus Christ, in the city of Pola of the Province of Istria.

Also, in the closing paragraph of the treatise he says:

This lengthy discussion Master Bonus of Ferrara, simple philosopher (Physicus subtilis), after having solemnly and carefully investigated, sifted, disputed, delimited and strengthened, has collected and arranged, in the year from the birth of Christ 1339,[2] being then a salaried official in Pola of the Province of Istria; in which (treatise) he has inserted that which he has learned of speculative and practical knowledge and the operation of it—defending it moreover and relying on the reputations and reasonings of the ancients and adding reasons of his own. Moreover I ask and adjure all those wise in these things, into whose hands this "Precious New Pearl" may fall, that they communicate the same to all men attentive to this subject, desirous of the art, and that they conceal it from the ignorant and from boys, since they are unworthy.

We have previously written a similar discussion in the City of Cragurius[3] in the year '23, which we destroyed on account of the great excellence of this. Here ends the Preciosa novella Margarita, edited by Master Bonus, the Lombard, natural philosopher of Ferrara, introducing to the Art of Alchemy, composed in the year of our Lord 1330. In the city of Pola in the Province of Istria.

This work of Petrus Bonus enjoyed a considerable popularity after the era of printing began. It was first printed in the form of a condensation, with other works by Lacinius in 1546 at Venice, and later impressions were in 1554 at Nürnberg, 1572 at Basil, 1602 at Mömpelgard, 1608 at Strasbourg, in the collection of works "Theatrum Chemicum" in Strasbourg 1659–61, in Mangetus, Bibliotheca Chemica, Geneva 1702.[4] Examination of the text of the Preciosa Margarita shows that Bonus based his discussion, not upon any recorded experience of his own, but upon a careful and conscientious digest of all authorities known to him. He very systematically cites these authorities to justify his statements, and nearly all these authors he cites several times, and some of them many times. Names of writers upon alchemical philosophy mentioned by Bonus comprise nearly all those whose works were referred to in the encyclopedic works of Vincent of Beauvais, Albertus Magnus, Bartholomaeus Anglicus, and Roger Bacon in the thirteenth century, and notably one important authority later than these—Geber, much cited by Bonus. The name of Geber is mentioned at least forty-one times in the Margarita. Names of authors cited by Bonus are Aristotle, Plato, Hermes, Morienus, Razes, Avicenna, Rosinus, Senior, Lilium, Melvescindus, Alphidius, Haly, Galen, Averroes, Mesue, Democritus, Alexander, Socrates,

[2] Probably a misprint for 1330 in the impression of Mangetus 1702. Whether this persists in all earlier prints is not known to the writer.

[3] Cragurius unidentified by the writer. Could it be a corruption by author or copyist for Cracovia, Cracow?

[4] This is the impression used by the writer.

Empedocles, Albumazar, Moyses, Arislaeus, Calid, Porphyrus, Melissus, Albohaly, besides a long list of names cited from the "Turba Philosophorum," a compilation of alchemical philosophy, of probably the twelfth century, in the form of a dialogue among ancient writers real and imaginary. Some of the above names are known to have been pseudonymous, but at that time they were generally credited and esteemed by writers. With the exception of certain early Egyptian and Greek alchemists, the list of Bonus comprises the popular alchemical philosophers known to the thirteenth century. The references to Geber are to his "Summa Perfectionis Magisterii," his first and principal work, which was supposed to be derived from the Arabian of the true Geber or Djaber of the eighth or ninth century A. D., but appeared after 1300 A. D. and is now known to have been written originally in Latin at about the time it was issued, 1300. Incidentally it is interesting that Bonus refers to Geber at least twice as Geber Hispanus, which is quite in accordance with the modern belief that Geber or Pseudo-Geber, as he is often called, was a Spaniard or Italian, who had studied in Spain.

Especially notable is the fact that Bonus makes no mention of Albertus Magnus, Thomas Aquinas, Roger Bacon, Arnald of Villanova nor Raymond Lully. Considering that in 1330 these authors had been dead for from fifteen to more than fifty years, and the high reputation that these authors enjoyed as alchemical philosophers and operators in the fifteenth and sixteenth centuries, the absence of these names from Bonus's list of authorities, otherwise so comprehensive, certainly demands explanation.

Is the date 1330 for the work of Bonus to be depended on as correct? There is another case of an alchemical writer whose writings were presumably undated and whom early historians of alchemy assigned to an early period, because no references were made by him to the authors in question. This was the writer known as the Monk of Ferrara, Frater Ferrarius or Efferarius.

Olaus Borrichius, in his account of celebrated chemical writers published in 1697, alludes to this man as a foggy or obscure writer, and says that though he discusses the writers of the Turba, Geber, Plato the chemist, and Morienus, he never mentions Villanova nor Lullus and therefore it appears that he must be considered as earlier than those authors. Lenglet du Fresnoy in his "Histoire de la Philosophie Hermetique" (1742) similarly says of the progress of alchemy in Italy: Pierre le Bon (Petrus Bonus) of Lombardy and the Monk Ferrari applied themselves to it about the same time in Italy. The former worked in Pola, maritime city of Venetian Istria, and published a complete treatise on the hermetic

science of which the Calabrian Monk Lacinius has since given a well-finished abstract. We have also the treatise of the Monk Efferari or Ferrari, though the latter is little read by connoisseurs, although in the midst of much obscurity we find some rays of light, but it is necessary to know how to discover them. He is believed to be of the end of the thirteenth or at least of the beginning of the fourteenth century, because while citing Geber, the Turba, and the hermit Morienus, he says not a word of Arnald of Villanova, nor of Raymond Lully, who were nevertheless two great masters who deserved to have been cited, if he had lived later than they.

Karl Schmieder in his "Geschichte der Alchemie" (1832) says of Ferrarius, Efferarius or the monk of Ferrara:

> We know nothing of his personality, and even his epoch can only be inferred from his writings. As in these he cites Geber, Morienus and the Turba of Arislaeus, but alludes to neither Albertus Magnus, Roger Bacon, Arnald nor Lully, he may provisionally be assigned to the years around 1200. Lenglet du Fresnoy places him surely too late—the year 1280.

John Ferguson in his "Bibliotheca Chemica" (1906) lists Ferrarius or Efferarius as "supposed to have flourished about 1200, the date 1280 put forward by Lenglet du Fresnoy being deemed too late. The argument for the date started by Borrichius is that, since he quotes the Turba, Geber and Morienus, but not Arnaldus or Lullius, he must have lived prior to the latter, that is about the beginning of the thirteenth century. I am not sure that this is conclusive." Ferguson states no reasons for this remark.

As it did not occur to the early historians to doubt the authenticity of the many treatises on alchemy attributed to Albertus, Thomas Aquinas, Roger Bacon, Lullus or Arnald, they naturally saw no other explanation of the absence of their names that seemed reasonable. Yet all these historians, in mentioning the work of Petrus Bonus, credit his date of 1330 without noticing apparently that he also while referring to Geber, the Turba, Morienus and many others yet also makes no reference to any of the five authors in question, and according to the same logic should have been assigned to a century earlier.

Schmieder says of Bonus that he was not a clerical, but master of liberal arts, lived at Pola in Istria, where according to his own data he completed the Margarita in the years from 1330 to 1339. He defends alchemy zealously against the doubters of his time, but seems to value but slightly the writings of Arnald and Lullus which were then in circulation, but considers that Geber alone shows the true path, thus allying himself with the Arabians. This is not a correct statement, for Bonus makes no mention whatever of Arnald nor Lully. A fact of importance respecting the correctness of the

date of the Margarita is that according to the results of modern criticism by Berthelot and others, the work of Geber—the Summa—was first issued not earlier than 1300. Indeed, Ernst von Meyer in his "History of Chemistry" (3d English Edition, 1906) states: "The oldest of these—the celebrated Summa Perfectionis Magisterii—was not before the middle of the fourteenth century." The work of Bonus establishes that it was probably somewhat earlier than the middle of the century. The argument by which the historians assign Efferarius to the thirteenth century also is contradicted by this fact, for this author also cites from Geber and therefore could not have been much earlier than Bonus, and he also does not mention Lullus, Arnald, Albertus or Roger Bacon, according to the historians.

On the other hand, it does not seem at all probable that these prominent authors wrote articles on alchemy, and that yet these articles should have all been concealed from the public for from a quarter to half a century before bursting on the alchemical public.

The more plausible explanation is that none of these writings was written at the time of Bonus or of Efferarius. This as already stated would be in accord with the tendency of modern criticism that all these alchemical works are forgeries and we may infer that they were issued later than the date 1330.

The question naturally arises why Bonus, writing at a time when alchemical writings were so generally prohibited that nearly all such works were issued either anonymously or under false names and either undated or misdated, should have ventured to describe time and place so specifically. To this it may be said that his work was very different in character from the great majority of alchemical works in that it makes no professions of accomplishment of transmutation, nor does his treatise pretend to give any directions, however obscure, professing to impart clues for such processes. In fact he clearly states that he does not believe that power to lie in the ability of human reason, and can only be achieved through the divine favor. As the prohibitory edicts were directed against alchemists on the supposition that they possessed the power to produce counterfeit gold and silver, and perhaps also because they were in league with evil spirits—Bonus might well have believed that his work was not such as was prohibited under these edicts. His was a purely theoretical discussion of alchemical philosophy. Hoefer in his "Histoire de la Chimie," speaking of the Margarita, says it is filled with theoretical considerations which bear witness to great dialectic ability, but to very little of the spirit of observation.

It would be a satisfaction to have some independent informa-

tion concerning the personality of this Petrus Bonus. The writers who have described his work give no evidence that they know anything of him which is not derived from his own manuscript. Borrichius, Lenglet du Fresnoy, Schmieder, Hoefer and Kopp all make mention of him and briefly characterize his work and accept the date of 1330 as the time of writing. There are two or three other titles of alchemical works ascribed to him, though of less popularity than the Margarita, but they do not seem to have conveyed any further information of the author.

The writer has found but one differing account quoted by John Ferguson in his "Bibliotheca Chemica" among other references. This is from a certain Mazzuchelli in a work published in 1762, "Gli Scrittori d' Italia," who refers to Pietro Antonio Boni, says "he lived in 1494, was a physician skilled in philosophy and took delight in alchemy and wrote Rationes pro Alchemia et contra." If this Mazzuchelli really refers to Petrus Bonus and his "Preciosa Margarita Novella," and his statements were based on fact, we should have to assume that Bonus had antedated his work a century or more, and that even then the alchemical works of Albertus, Lullus and the others were not yet known to him. While we lack reliable knowledge as to the dates of their appearance, it seems hardly credible that they were not at this time known to the chemical public. It seems more reasonable to assume that some other person is referred to or that there is some confused or mistaken identity in Mazzuchelli's reference.

In a recent critical translation into German of Geber's work, Dr. E. Darmstaedter (Die Alchemie der Geber, Berlin, 1922) calls attention to the fact that in the earliest known manuscript in Munich, of the Summa Perfectionis of Geber, attributed to the end of the thirteenth century, the titles of three other works are mentioned, De Investigatione Perfectionis, De Inventione Perfectionis and Liber Fornacum. Darmstaedter adds, "Whether the works known under those titles and here presented in German translation are really by the author of the Summa Perfectionis, or are elaborations of a later period will not be here discussed. This much may be said, that no manuscripts of the books De Inventione and Liber Fornacum are known to me and these writings are found in but few printed works." Darmstaedter also notes that the earliest manuscripts of the "Summa" lack the more elaborate titles, Perfectionis or Perfectionis Magisterii, that occur in later manuscripts and in printed editions.

In this connection it is interesting to observe that Petrus Bonus in his numerous references to Geber cites from his "Summa" under that title only, never mentioning it under a more extended title.

Also when discussing that work he expressly says, "His other work De Inventione Perfectionis which he refers to as preceding this, we have not yet seen."

These facts are in harmony with the authenticity of the date of 1330 as given by Petrus Bonus, and are of interest also as bearing upon the disputed question as to whether the other works besides the "Summa" attributed to Geber are genuine or the elaborations of later writers.

The reasonable assumption on the basis of all present information is that the Margarita was correctly dated, shortly after Geber's "Summa" had appeared, and that at that time the alchemical works attributed to Thomas Aquinas, Albertus Magnus, Roger Bacon, Raymond Lully and Arnald of Villanova were not known to Bonus, because they were not yet written, being forgeries of periods considerably later than the lives of those authors to whom they were ascribed.

AMERICAN TENDENCIES IN GEOGRAPHY

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GEOGRAPHY and geographers both are commonly regarded as having an existence beyond the pale. To set forth plainly how and why they have come to be thus outlawed is a task of the same difficulty with defining the content of geography. Indeed, the two problems are linked up with each other. Geographers are under a cloud because what should properly comprise the subject-matter of geographic studies is itself involved in mists.

To be sure, distinguished personages of various times have been called geographers. Darwin and von Humboldt would be named in such a list. Analysis of a catalog of worthies, classed as great geographers, would, however, immediately disclose that almost every person included had attained distinction independently of geography per se. Some, it would be found, earned enduring fame because they were great travellers; others were cartographers of note. Certain individuals are remembered because of the literary excellence of their works, others for their assiduous labors in compilation. In each such instance there could be noted "something else again" besides geography to insure the world's acclaim.

There might be a large tolerance of the indicated failure of geography to establish itself as a clearly defined science were it not for the fact that, in America at least, almost any individual who is led to attempt an appraisal of the subject is thereby also made conscious of a discontent with his experience of geography as a study in school. The geography text with its many pictures and diagrams promised much; the actual conning of that text in successive lessons usually proved tiresome and disappointing. There was little enthusiasm for the systematic study of geography while it was being done, and later on in life there developed a realization that in failing to get from geography what it should contain something fundamental in education had been missed. American geographers have not been unaware of this situation and the text-book writers of their number have striven to remedy the difficulty. But despite these endeavors and the changes in the content of the texts and the presentation of the material which have resulted from them, and which should in fairness be counted as advances, instruction in geography from the elementary schools up through the universities is admittedly unsatisfying.

All this is by way of introduction. It is proposed here to inquire why geography has failed to establish itself as a science occupying a clearly defined field and what its defects as a school subject have been and are; then, further, to present the attitude of American students professionally engaged in geography towards the problem and the possible significance of the tendencies now apparent.

The province of geography does not, on review, appear especially difficult of simple definition. It is the science concerned with the description of the earth and its inhabitants. With regard to the first clause of this formulation, the description of the earth, there is no occasion for argument. That business is assigned to geography and to geography only. The existence of geology, physiography, meteorology and oceanography as distinctive fields for study and investigation does not at all detract from geography. These other earth sciences are concerned with the examination and discussion of the origin and nature of particular phenomena; thus of the inner structure and outer form of the earth, of the air which surrounds it and of the water which fills its hollows. These special branches contribute to the subject-matter of geography and recognize that it is their function to do this unreservedly. From geology geography derives facts relating to soils and mineral deposits; through physiography geography is informed of the shape and features of mountain and plain, meteorology provides knowledge and understanding of climate, and oceanography of the disposition of ocean currents and the rise and fall of tides—among other things in each case.

The description of the earth itself, its physical reality, to which these children-sciences of geography dutifully contribute, is a vast task. It involves, to begin with, diffusion of knowledge regarding the distribution of the lands and the seas on the earth and of their particular configurations, first as to absolute position and second in relation to each other. Further, it does not suffice to indicate, merely, that a large island lies in latitude 20° S. and longitude 46° E. off the east coast of Africa; it is necessary that the island should be identified by its name label, Madagascar.

It may be set down, therefore, as a dictum that before the student can make progress in other phases of geographic learning he must have attained an adequate equipment of this fundamental knowledge of locations and name labels. But it is exactly that training more than anything else which he fails to get under the modern system of geographic instruction in American schools. The name-label phase of locational geography was emphasized more a generation or two ago; indeed, it was then carried to absurd extremes. The student, for example, was then required to learn, and

to repeat in alphabetical order, the names of all the counties of the home state. If there had been insisted upon, also, at that time, an equally glib knowledge of the location of each of these counties within the state the training in calling the roll of their names would not have been so altogether futile as it was. The other, and modern, extreme in elementary geographic instruction is marked by the fact that students have been known to enter undergraduate courses in universities uncertain whether North America is a continent or a country.

It should be recognized, and acted upon, that the first steps in geographic study, as with other beginnings, must be painful drudgery. There is no fun in learning to read, to write, to spell, to do sums. Why should it be expected that in geography one will be exempted from the toil of the neophyte? Yet that seems always to have been the assumption with geography. The older elementary texts, while more insistent on names and locations, were undiscriminating as to the relative importance of the items to be inculcated; which was bad enough. But worse was the fact that in them it was sought to sugar-coat the locational pills with an ill-assorted miscellany of supposedly interesting and pertinent facts and statistics. The effect of these gratuitous insertions was chiefly to distract the student's attention from the task in hand, that of mastering locations and names. Realization of the defects of the filler material has led text-book writers of a later time to devote their energies to making the interlarded stuff rational, coherent and interest-compelling. In this ambition they have been quite successful. But the changes they have wrought have thrust the fundamental, locational geography so far into the background as to depose it almost completely from significance.

Beginnings in geography, as in other studies, are mnemonic. We can do 9 x 8 and 12 x 12 without setting down any figures on paper. But 13 x 17 stumps us because we never learned multiplication tables to include those figures. As with the multiplication tables, so also in geography, the locations, which are the 9 x 8 part, and the names, which are the result part, 72, should be learned by rote. There are of course limits beyond which it would not be profitable to go, just as there are limits with multiplication tables. In America the states of the United States should certainly be mastered, and perhaps as an extreme the counties of England—the counties of England because these have a historical and literary significance for an English-speaking people not possessed by the kingdoms of old Germany or the provinces of France.

In the beginnings of geography it should be as with, "c-a-t, cat," and "the cat is on the mat, m-a-t, mat," in reading and

spelling, and not, "the cat is kin of the lion and tiger and other beasts of prey." It is not meant that in geography there should be no devices to facilitate the mnemonic processes and to give the training significance. Only that the distractions, the attempts to rationalize, shall be ruled out in the first steps. Thus with third-year and fourth-year students there might be used the device of a suspended globe, as large as could be conveniently got at by children of the stature then attained. On this globe the outlines of continents and islands would appear and the latitudinal and longitudinal net. The surface of this globe would be perforated, further, with a multitudinous system of sockets, of varying size and marked perhaps with rims in different colors. Each socket would be the place for planting a flag bearing the name of a continent, a state, a river, a city. It is unnecessary here to elucidate further in regard to the mechanical details. But it will be appreciated that, however the initial drill in learning the locations and names is carried out, the student who, on test, being given an assorted lot of flags could without hesitation plant each one in its appropriate socket on such a globe would have a knowledge of locational geography very few of us possess.

After that the student could pursue with profit and interest, and without harm, the study of the average "First Book" of the elementary geography texts now in use. If, meanwhile, he could also, through "nature study," have been introduced to the phenomena of orientation, day and night, seasons, and to the reading of maps, his grounding for the study of the first book would be well rounded out. If, by observation of the North Star or the noon position of the sun from *different* points, the fact of parallelness of north-south lines could be established, for example, that would be enough. At this stage there would be no need to go into explanations. Similarly, the first steps in map reading could probably be taught best by using a simple map showing points that the student might reach by walking, but which were out of sight from the point of departure. The changes in direction of the route followed and the symbolism of the map would by this means be made self-interpretative.

The considerable digression from the main theme in which we have indulged has seemed necessary because the specific details presented make clear what a general statement only of the situation might have left obscure. Reverting now to the definition and the problem of geography, as set down in an earlier paragraph, it is of course evident that when locations have been learned we have only proceeded to the point of knowing what is to be described. An even more arduous task awaits, that of becoming acquainted with the

physical equipment of the earth. Much of this knowledge, too, must be gained by tedious exercise of the assimilative faculties, though a little salt of understanding may be used to season the diet. All this which relates to name, location and objective reality in the world is geography, however; no one disputes that, and it is expected of the professional geographer that he will gather these facts, classify and correlate them, and present them in appropriate form.

But when we enter upon consideration of the second clause of the definition of geography, as given, and which reads, "and of its inhabitants," we have to deal with a much more elusive and controversial topic. As with geology, and so forth, on the inorganic side, so also we find that botany, zoology and anthropology, on the organic side, are willing and able contributors to geography. On the other hand, history, economics and sociology have held themselves distinctly aloof; have shown no disposition to regard it as part of their duty to aid in the elucidation of geographic problems. More, they ask nothing, and will accept little, from geography.

That history, economics and sociology have set up a sort of "No Thoroughfare" sign against geography is one thing. Another is that geography has got itself all muddled up in attempting to include with her material the content of a branch of knowledge that as yet lacks a distinctive name. It might be called the science of agricultural practice, commercial procedure and of industrial processing, or, more concisely and generally, technology. Economics has adopted certain phases of the part termed "commercial procedure," and chemistry stands sponsor for some of the subject-matter of "industrial processing." But much of industrial processing and nearly all of agricultural practices have been saddled onto geography.

Here we digress again for a little to point out the second of the futilities in school geography. I open at random the most recently published of the geography texts, one which is used very generally in American elementary schools. I chance upon page forty and find that the whole of it is given to a description of a blast furnace and the smelting of iron ore. On pages 106 and 107 of the same book I learn how a sugar-cane plantation is conducted. On pages 142 and 143 of another popular text the procedure of a round-up of cattle on a western ranch is set forth quite exactly and the efficiency of modern meat-packing plants is exemplified by inclusion of a list, in detail, of the utilization of the by-products. The citations given are only samples. These and other books contain page after page of the same sort of material. But is such matter geography? Hardly. And if it were, why stop with telling how iron is smelted,

why not teach as well how to assemble an automobile or how to extract radium from its ores?

It may be desirable to teach elementary school pupils how corn is cultivated and how hardwood floors are waxed. But if these children are supposed to be studying geography they should be giving attention to matter germane to that subject and not to incidental accounts of how men deal with certain materials. It is owing to the inclusion of a multitude of such extraneous items, in what purport to be geographic texts and books, that geography is so generally considered a repository for miscellaneous odds and ends of information for which a place has not been found elsewhere. Incidentally, it may not be amiss to suggest to persons who are struggling with texts and courses entitled "Introduction to Science" that what they really have in mind is to put before students in organized form the sort of information that the geography-text authors endeavor to comprehend in their descriptions of a blast-furnace and a packing plant. Discriminatingly selected and systematically presented, such topics could be made the basis of a worth-while course, in the junior high school, say.

But this text-book aberration can be corrected. A more serious difficulty is presented in the non-cooperative, self-sufficing attitude in relation to geography evident in historic, economic and sociologic studies.

While the writings of historians, economists and sociologists, in general, do not directly express the exclusion sentiment herein imputed to those sciences, they do reflect it. It seems to be felt, in some degree, by workers in each of these fields that the world looks to them for an explanation of the present state of man. The historian apparently considers that when the nature and succession of institutions, the character and motives of personages and the march of events are adequately known and understood the present ordering of the world and of mankind will be sufficiently elucidated. Similarly, the economist would have us gather that the evolution and contemporary status of man's utilization of the earth's resources, and of his dealings with other men, are the key to the problem, and the sociologist would find its solution in the history and nature of man's gregarious activities. On the other hand there have been geographers who insisted on a "rigid determinism," that is, a control and direction of all human affairs past and present by geographic influences, the dominance of environment.

The list of phrases current in discussions of the import of the geographic factor on human affairs is already so long that it will do no great harm to add another to the number. This will be "determinism through adaptation." By determinism through

adaptation it is meant to express the fact that, whereas each geographic environment presents certain opportunities to mankind, the nature and degree of the utilization of these opportunities will depend on the kind of men who enter upon their exploitation. A given group of men will therefore be successful in the degree that its activities are permitted by and suited to the place. Some sort of adaptation or adjustment there must be or the group will not survive. So much there is of determinism. But it does not follow that the previous history and personal characteristics and habits of a people will have no bearing on the adaptation which develops. These factors will affect greatly the kind or nature of the adjustment that will be attempted. When agricultural settlers from the humid east of the United States first invaded the grasslands of the semi-arid border of the Great Plains they attempted to occupy the new areas under the system of farming and living which was successful in their old homes. But this system did not fit the new environment. Consequently, there had to be an adaptation involving many modifications of the old system. It was found, for example, that six hundred and forty acres, rather than one hundred and sixty acres, were needed for a homestead in the semi-arid country. Had these settlers come from other dry lands they might never have attempted the extensive utilization of the land which the immigrants from the East have now established, but would have, instead, confined their activities to narrow alluvial lands and limited tracts of irrigable acres. The environment fixes certain conditions; man adjusts himself to these conditions variously.

Grant that it is the business of geography to describe the earth and its inhabitants—chiefly man, then one may ask: In what spirit, from what viewpoint shall that description be presented? And the answer is: It should be an interpretative description. From geographic science we should expect to gain an understanding of man as he now is and wherever he is, in relation to his environment, inorganic and organic. Here the reader may exclaim "Huh, that is assigning to geography the most significant rôle among the social sciences." Precisely that. Geography should be the correlating and synthesizing science. Other branches of knowledge have two functions. They are concerned with the investigations of special fields, and in some degree they serve as handmaidens to geography.

It may not fairly be said that in this absurd pretensions are raised for geography. It is a position already tacitly granted to geography. If one is seeking information about Tasmania and Tasmanians of the present one does not turn to histories or economic or sociologic works. Rather one seeks a book or an article on the

geography of Tasmania. If it is desired to know the order and origins of the Tasmanian culture, then historical and sociological writings should be consulted; for the operation of governmental institutions and the industrial practice, works on political economy are indicated. The difficulty under which geography labors is not so much that it is denied the function of correlating and synthesizing science as that geography and geographers have failed to perform their duty. The sought-for, truly *geographic,* interpretative book or article on Tasmania and Tasmanians is probably not to be had.

Tried and found lacking would therefore seem to be a sufficient explanation of the low estate of geography. Why make a pother about the fact? Because only a few years ago American geographers in formal assembly were evidently agreed that regional geography of the indicated, interpretative type was the major problem of the science. Since then part of this group, at least, has been converted to a new point of view and method of approach to geographic problems, and that one which threatens to involve the science in a new series of mazes without giving promise of any adequate return. The true, interpretative geography is now said to be "human geography" and it has side issues, like "land utilization," which have an economic bearing.

And this, too, just at the moment when for the first time there seemed assured the active cooperation of the economists and perhaps of the historians and sociologists. An eminent economist recently came before a meeting of geographers and presented the case of economic science as in need of help, and the help wanted was from geography and geographers. The motto of the economist's appeal was: "Under all the land." And the geographers, who have long been protesting against being classed as pedlars of irrelevancies, instead of eagerly accepting the implied invitation to geography to give point to economics by answering, "We will pursue our regional studies with vigor so that you may have at your disposal the geographic facts which will permit you to apply economic science," replied rather: "Yes, yes, we will adopt economic methods; we, too, will study man's activities, we will come at a true understanding of geography by use of statistics and other befuddlements." They overlooked altogether that the motto of the economist's appeal was "Under all the land." A strong program for straightforward research in regional geography, which had met with approval some years earlier, had evidently been altogether cast aside. Instead these geographers seemed desirous of giving the impression that they were engaged in labors extremely recondite, requiring long-continued and arduous efforts to secure results.

If the issue here presented was one that concerned professional geographers merely there would be little excuse for bringing it to the attention of readers outside that circle. But the matter does have a broader significance. It is important that instruction in geography should be sound and to the point. It is also important that geographic research be directed to the securing and preparing of adequate and authoritative, interpretative, regional descriptions to the end that political, economic and social adjustments may be made on a sound basis. There exists a great demand for such studies. The public seeks geographic enlightenment. Travel books have a wide sale. A certain geographic magazine enjoys a tremendous vogue because it publishes each month a multitude of pictures showing lands and peoples far and near. These illustrations depict regional geography. The age of exploration has almost passed, but the average man is now engaged in making his own voyages of discovery. If geographers will not supply him with illuminative text the other fellow can at least make his own interpretations from the pictures so freely provided.

In order to understand why the pursuit of "human geography" is apt to lead to futilities, it is necessary to be clear as to how it differs from the interpretative, regional geography herein urged. Those who adopt human geography as their method of approach to geographic problems seek to find in human activities and in the results of human activities the clues to geographic understanding.

Thus, for example, it is pointed out that the arrangement and clustering of human habitations in one region is different from that of another; accordingly, the reason for this difference is to be sought out. By analogy, assume that a woman appears in a certain sort of dress. Then by looking at the dress it is expected that one should understand the woman. There is something of truth in the philosophy here followed, and it may be suspected that modern femininity has come to the same conclusion. Hence, perhaps, the shedding of raiment in order to be more securely inscrutable. In flapper guise the maid of eighteen may not be singled out from her of thirty summers. Nevertheless, it would probably be conceded that Eve stood more revealed in the Garden of Eden than when garbed in mid-Victorian propriety. Human geography seeks to understand the environment by noting what the response to it has been.

The influence and works of certain European geographers, especially of P. Vidal de la Blache and, more recently, of Jean Brunhes, are in large degree responsible for this trend. A quotation or two will serve more truly than much analysis to give acquaintance with the method and manner of these leaders. Thus Brunhes:

But if we cast a general glance over the earth, we soon see a whole new and very extensive series of surface phenomena; here it is cities, there it is railroads; here it is cultivated fields, there it is quarries; here it is irrigating canals, there it is salt marshes; and in all lands are more or less dense masses or groups of human beings. These human beings are, in themselves and by themselves, surface facts and therefore geographical facts. They live *on* the earth. They are subject to atmospheric and terrestrial conditions. They belong to certain climates, to certain altitudes, to certain zones. Besides they live *from* the earth; it is by subordinating themselves to natural phenomena that they assure to their bodies the necessary conditions for life and growth and to their faculties, development and expansion. . . .

The ensemble of all these facts in which human activity has a part forms a truly special group of surface phenomena—a complex group of facts infinitely variable and varied, always contained within the limits of physical geography, but having always the easily discernible characteristic of being related more or less directly to man. To the study of this specific group of geographical phenomena we give the name "human geography."

And this from P. Vidal de la Blache:

The *characteristic quality* of a country is thus a complex thing resulting from the delicate and varied interaction of many factors.

As Brunhes suggests, a certain "spirit of finesse," of mental suppleness, is essential to carrying on the type of studies he outlines. The kind of geographic description which results from this attitude is exemplified by the following, again from Brunhes.

The village type is in itself a geographical fact, both in the way it expresses the nature of a whole region and in the way its appearance and position depend upon its immediate surroundings. The picture of the village of Salo .....: Slopes almost entirely green, of two greens combined, one bright, the other almost black, forming from afar one somber color; on this background, in no sharp contrast, are light or dark gray rocks. What does stand out upon these high and steep but harmonious slopes, what gives them life, what produces the opposition of shades and lines, is the white village against the dark background. Each village spreads horizontally along the hillside, breaking the main lines of the long slope, its dazzling points forming one level curved line, relieved and dominated by the vertical shaft of the bell tower. And as if to complete the harmony and to reproduce in exact miniature the deep, dark color scheme of the whole, each long white village is broken by dots of shadow formed by the arcades, and the whiteness of each house is broken by the dark window openings.

Word pictures such as this may have a place in the ultimate content of geographic literature.[2] But it is work which may be likened to that of gleaners in a harvest field, or of decorators in a nearly finished house. It is interesting to note that even Brunhes confesses that it is "difficult to make out what is really and strictly geographical in the manifestations of human life in vast dissimilar

[2] The chapter by an American geographer in the English translation of Brunhes's book, "Human Geography," is a very nice piece of regional geography even though it was intended to be a sample of human geography.

settings," "wholes as complex as France or the United States." Hence, he suggests, simple units, five types of little, geographical worlds, seem especially marked out for the observations of the human geographer. These are islands: the islands of the sea; the islands of the desert, oases; islands of population in arctic wastes and equatorial forests; the island of the closed mountain valley, and the island of isolated mountain areas surrounded by plains. And while Brunhes may be warranted in thinking of the area he proposes to study as such an island it is nevertheless regrettable that the "spirit of finesse" displayed in Brunhes's studies should inspire a young American geographer to declare publicly "that although he had been in Patagonia and other far places he was done with geographic studies of extensive and remote areas until he had mastered in detail Chicago and its environs for thirty miles round." What a terrible ambition. What depraved geographic taste to desire to be engaged indefinitely in grubbing about *Chicago!*

Human geography will make its followers unable to see the forest because of the trees. Another young American geographer is already involved in what may be considered one of the outgrowths of human geography, namely, "land utilization." He expresses the objective of land utilization studies to be (in part) as follows:

> In the study of present utilization the condition of the land is under scrutiny, as to kind of use, productive returns of each type of use, and the effectiveness of kind of production as related to type of land. In this manner the area may be broken up into smaller parts, each characterized by a distinctive system of production, and usually differing in returns as well. In so far as this type of study can be expressed by a map, the map will reproduce the landscape as a mosaic of differing economic practices, usually, though not necessarily, closely related to different types of land.

The idea seems to be to mate economics and geography for the production of a mongrel which shall have something of the qualities of both parents. That the mongrel should exist is bad enough; that geography is expected to play mother to the cur is even more objectionable.

Perhaps that is condemning a worthy project without fair trial. However, the same young geographer who proposes this research in land utilization also penned these lines comprising part of a study of the regional geography of the Ozark Highlands:

> The main roads follow ridge tops. Their location is determined by low cost, freedom from floods and freedom from erosion. They are passable throughout the year, but serve directly only the settlements on the ridges. Over large sections these settlements are not flourishing, nor as promising for future developments as the valley settlements. It is notorious that the traveler on the main roads sees very little of the better land. The ridge roads are separated from the valley farms by steep hills. Connection between the two is made by

rough and often badly washed side roads. The secondary roads that follow the valleys are subject to flooding with every freshet and are often washed out. Fords are innumerable, bridges few. The location of roads was determined by the easiest lines of travel. . . .

Here one begins with the first sentence to get an understanding of the Ozark country in its broader geographic aspects. And despite the largeness of the drawing it is an intimate picture. Why struggle with the statistical details of census figures, tax assessments and crop returns and bring forth a mouse, while we still lack, for the larger part of North America, the effective delineations of regional geography such as this man has provided for the Ozark area?

In part human geography is a reaction to the rigid determinism and the unsupported, or rhetorical, generalizations with regard to geographic controls and influences which preceded it. Human geography proposes to be inductive (with occasional lapses) whereas the earlier studies were deductive. It is not to be denied that the anthropogeographers, of whom Ratzel was the leader, struck by the potency of certain obvious geographic relations in shaping the course of history, were encouraged to range far afield and indulge themselves, and the world, with such fancies as that the love and cultivation of beauty by the ancient Greeks was a direct response to the variety and interest of the Grecian landscape.

Like the modern "human geography" these speculations originated in Europe. Meanwhile, however, there was developing in America, initiated by the studies of Dutton, Powell and Gilbert, and carried forward to a rounded whole by the master work of Professor W. M. Davis, of Harvard, the science of physiography or the explanatory description of land forms. Davis showed that land forms, like life forms, go through an evolutionary cycle, have a life history. Mountain, stream valley and shore line have each their successive steps of development, and in the same stages have comparable characteristics. It becomes possible to analyze landscapes of the most complicated type, to trace out their past and to predict their future forms. Moreover, once a landscape was identified by characteristic earmarks to belong in a certain category and stage, it also followed that it must exhibit certain other qualities and conditions that go with the form in question. Henceforth, to name a particular physiographic form was to describe the landscape as well. Relief forms from all over the world could be compared with exactness and their relation to human activities appreciated, even though the train of consequences did not everywhere appear to be exactly the same.

From this systematic knowledge of relief forms there grew up

the concept of physiographic provinces. Further, there has developed a general accord among American geographers as to the delineation of the physiographic provinces of North America, and more particularly, those of the United States. During the period in which this sorting out of the provinces was being done it was thought that, once satisfactorily outlined, such areas would provide the fundamental units on which regional geographic descriptions could be based. But it was found that they would not so serve, that something more was needed. To express this requirement of a regional, geographic unit dependent on the physiographic province, and yet distinctive from it, the term "natural region" was suggested.

The natural regions of North America have not yet been outlined satisfactorily. It is recognized that, second to physiographic expression, and perhaps of equal importance to it, the geographic factor of climate must be considered in fixing upon natural regions. The distribution of mineral resources and of avenues of overland routes of transportation must also be taken into account.

In the case of climate the accumulation of meteorological data has now progressed to the point where it is sufficiently comprehensive to permit its use in researches of a synthetic kind. A number of geographic students are at present engaged in this task of developing climatic characterizations. It is a work that promises much. As their various efforts are in turn correlated we begin to see that certain combinations of the weather elements give rise to distinctive climatic types. With reference to the human occupation of the earth each of these climatic types will have a definite and convincing relation. And when the climatic type is fitted to the physiographic province we can expect to see an emergence of natural regions in their larger units. On the other hand, certain areas indicate themselves so clearly as natural regions through the concurrence and systematic correlation of all the geographic items they exhibit that they do not need to await analysis for their delineation. They almost mark themselves out on the map. Consequently, another group of American geographers is engaged in the task of fixing upon these recognizable natural areas, with the expectation that their characteristics will furnish clues for further divisions of the land into areas of geographical unity.

In these several endeavors true and orderly progress may be discerned. Surely it is well to have knowledge of the gross anatomy of the body before attempting histological studies. Here we revert again for a moment to the land utilization project. One young promoter in this field has been quoted. Another energetic worker with similar ideas has recently published a paper dealing with the dis-

tribution and possible densities of population in relation to the ultimate food supply. His analysis is clear and his classifications are good. But he too urges that the immediate task of the geographer is the undertaking of an infinitely detailed survey of the land surface of the world. He is more rational in that he proposes that this survey should proceed from the large to the small, from world regions to physiographic provinces, narrowly subdivided, to natural districts which, with him, are very narrow areas in regions which already have a considerable density of population. With this scheme of procedure no fault need be found. It is, however, the end result, the exact knowledge and delineation of the small natural district, in which he is primarily interested. A significant difficulty, then, with his proposal is that what he wants done is something which will be indefinitely deferred. Recognizing this difficulty the other group of land utilizers have in view solving the dilemma by making their attack through study of the human geography of the small area.

Wide regions of the earth's surface have not been accurately mapped as yet; the topographical mapping of the United States under governmental auspices, and supported by large annual appropriations, will require at best twenty years more for its completion. Hence the very base for the detail studies is lacking. Again the prodigious effort in research necessary to carry through such a project in any reasonable time would require a force of geographers vastly greater than the available supply, all to be provided with a livelihood while engaged in the work. As it is, geographic studies are almost all desultory, engaged in by individuals as their enthusiasm or interest may dictate, with some aid from public and private sources. That will no doubt continue to be the situation. Systematic and comprehensive histological geography—yes, perhaps two hundred years hence.

Aside from the physical difficulty, there is another even more vital defect in the "land utilization—ultimate population density" proposal. Unostentatiously slipping into and out from the discussion is the suggestion that the findings of the survey should be related to a maintenance of the present standard of living. Evidently even vaster numbers of people, than at present, are in the future to be doomed to poverty and misery. Surely not an optimistic outlook. And if the standard is to be raised, to what degree? Here certainly we leave the domain of the geographer and enter the realm of the sociologist and of the economist.

In passing, one virtue of the human-geography method should, however, be noted. In making the approach from the human-activity side many observable items of the human occupation of the

earth will be immediately and clearly found not dependent on, or related to, the physical environment. They may be dictated by circumstances, historic determinations or by perversities of human nature, matters of sociological development. Whether or not these should be considered as instances of minor maladjustment to the geographical situation will depend on the point of view. In any event, thus brought to light, they can be eliminated from the geographical problem, which will then by so much be cleared up.

Reliable and sufficiently comprehensive census figures and statistics of production for the world have been available only within recent years. As these came to hand with satisfying completeness a science developed for showing graphically the facts of distribution contained in the figures. The map pictures to which this gave rise were fascinating studies, they made safe deductions possible where before there could be speculation only. Also they directed attention very emphatically to man's being and activity on the earth and the results of such activity. In part, then, human geography got its impetus legitimately enough from the accumulation of census figures and the demand that these be analyzed geographically.

A word more, finally, with regard to the program for geographic instruction. When the facts of locational geography have been patiently learned by rote, when through simple observational study the young pupil has been made conversant with the elements of orientation and of map reading, and after he has been introduced to the position of the noon sun as the clue to day and night, seasons and longitude, then he will be ready for a systematic study of the regions of the world. It is not essential that the text used for this purpose should be built up, in monotonous succession, of topics headed, location, size, physical features, climate, soil, chief products, cities, etc., for each region studied, as was once the case. Instead, it should be quite possible to develop the study of each region as related to some central theme, which will give expression to the dominating geographic factor in that area. The treatment may even be keyed to an "emotional" pitch as one critic of elementary geography suggests it should be. Certainly it should be inspirational. But the demand for interest, through variety and liveliness in the manner of presentation, is not, however, to be construed as giving excuse for including accounts of how blast furnaces are operated, corn cultivated or how cattle are branded. The rule should be to include as much as is practical of geographic significance and to discard altogether the non-geographic items.

As, under the prevailing system, geographic instruction terminates in the grades, and in some cases is not carried beyond the sixth grade, the "spiral" treatment now in vogue is altogether wrong. By this method the pupil in the sixth grade or in the sixth

and seventh grade goes over the same ground in a second book that he has covered in the lower grades. The only differences are that the content of the second book is greater, and that the material is not organized in the same way as in the first book. Furthermore, the individual who completes a high school course of study probably does not get in the majority of cases any additional instruction in geography.

If the unessential matter were omitted in both books much of the fuller statement of the second book could be included in the first book. Then the way would be cleared for an intensive study of one continent, North America, in, say, the seventh grade. While the purpose of education, ideally, is to prepare the individual for living rather than for earning, it avails nothing, in furtherance of this ideal, to be blind to the fact that the student whose formal education in geography will stop with completion of the seventh grade is in greater need of vocational than cultural training. In the majority of instances, moreover, it is probable that the life interests of such students will be focussed on a very narrow region about their home areas. If he will never be able to see that far in after life the student will have but little cultural gain through being provided with a world horizon in the elementary schools. On the other hand he will derive great cultural, as well as material, benefit through having a detailed knowledge of the geography of his home region, his home country and his home continent, North America.

If circumstances permit continuance of study beyond the elementary grades geographic instruction through the high school years might include elementary physical geography, elementary technology (perhaps under the guise of commercial geography or industrial geography or introduction to science), elementary meteorology and climatology and elementary astronomy. Then the student would be ready, during a college career, to pursue studies in systematic, regional geography concurrently with studies in history, economics and sociology.

No doubt there will always be those who will insist that the greatest human successes are achieved by the individuals or groups that best understand mankind and men's motives and activities; hence that history and human geography are indicated as the studies especially to be emphasized for the promotion of successful living. But to this it may be replied that if all men knew all the earth, its regional possibilities and limitations, and would adjust themselves to these natural conditions and cooperate in the development of the world environment, much that distresses in man's behavior and which one would learn to circumvent through knowledge of human geography, history, economic and social science, would tend to disappear.

THE PROBLEM OF AN AUXILIARY INTERNATIONAL LANGUAGE AND ITS SOLUTION

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In its report on the scientific value of an artificial language published in 1887 the American Philosophical Society points out the harm done to science by the application of many languages as follows:

> All nationalities have the honor of publishing their scientific productions in their own languages so that there are now scientific works not only in all the principal European languages, but also in Rumanian, Czech, Magyar, Armenian, Japanese. The confusion of languages in scientific publications has grown to such an extent that the great scientist Max Müller has been induced to appeal—but in vain—to his confrères to restrict themselves to the six languages, English, French, German, Italian, Latin, Spanish. This, however, would be a very insufficient remedy. For where is the student who could learn only to read those six languages?

The preceding remark is clearly illustrated by the experience of Professor William Marshall in his study of the epoch-making theory of my early friend, Professor Albert Einstein. Professor Marshall summarizes the difficulties of studying the theory in the following words:[1]

> All the work about the theory is scattered through research journals in some six languages so that it is not very accessible. Fifty or more articles include those in three languages, only those which an ordinary mathematician and physicist could read without too great an expenditure of time and energy.

No better illustration of the detrimental effect upon scientific investigation caused by the multiplicity of language could be given than this embarrassment of Professor Marshall in his study of a new theory which bids fair to revolutionize physical science.

Another illustration is furnished by Professor Einstein himself when he lectures in foreign countries. During his visit to America in 1921 many American mathematicians, physicists, philosophers, etc., came from all parts of the country to hear the most ingenious physicist himself expound his theory. But, with the exception of the German-Americans of the first generation, very few of the listeners were able to follow the speaker properly. He had for his lectures no language that he and his hearers might have understood

[1] *Popular Science Monthly*, May, 1914.

equally well. He did not want to speak in a language in which, at best, he would have been far inferior to them. Free lectures in an unfamiliar tongue would have imposed upon him a great burden without enabling him to express his thoughts with as much clearness and precision as in his mother tongue. Any foible shown would have given his listeners cause to look down upon him benevolently. He, therefore, chose his mother tongue for his lectures to the great disadvantage of the American students and scientists. Scholars in other countries have the same experience since Professor Einstein never uses any but his mother tongue in public lectures.

Merchants engaged in international commerce suffer even more than scientists from the want of an auxiliary international language. Besides increased expenditure of time and energy they have to bear increased expenses for interpreters and for special clerks needed in their foreign correspondence. Similar difficulties are encountered by those traveling through foreign countries for professional and other reasons.

The importance of an auxiliary international language for diplomacy has been evidenced not very long ago at the Russo-Japanese peace conference at Portsmouth. The beginning of the negotiations was retarded for several days because the plenipotentiaries did not understand a common language and interpreters could not be had quick enough, a fact that was then prominently discussed in the daily papers. Meanwhile the whole world was waiting with great concern for the final act which was to conclude an international tragedy. Also, at the termination of the latest and greatest world tragedy at Versailles an undue delay of the negotiations took place. Perhaps it was caused partly by the inability of the American delegates to converse in the French language. At any rate they certainly were not able to argue the American cause by means of the French language as well as the Frenchmen could argue theirs.

The unequal position of the various participants in an international affair can be observed in all international gatherings. The tendency towards international institutions has been growing more and more owing to the great progress of science and to the immense improvement of the means of transportation. There are international societies for the promotion of science, technique, commerce, world peace, morality and wireless intercommunication. Especially to be mentioned is the International Association of the Academies. These societies convene congresses and at such occasions the want of an auxiliary international language renders intercourse between the participants very difficult and causes great inconveniences to

most of them. The position of the majority of the participants is disadvantageous, while that of a few others whose language is used at the gatherings is very favorable. In this respect the eminent linguist Hugo Schuchardt makes the following pertinent remark in a report on the international language question submitted to the Vienna Academy of Sciences in 1904:

> The diversity of language hinders international communication in numerous instances, and where it can take place, either in writing or in speaking, it is only exceptionally effected in an entirely satisfactory manner, *i.e.*, so that the two parties would understand each other as well as two compatriots do and that one of them would not be overburdened.

The preceding considerations show clearly the desirability and the ever-growing need of an auxiliary international language. The nations will never concur in selecting one of the living languages for that purpose. For they will not consent to one nation gaining immense advantages thereby, especially in commerce. Besides, a living language is much too hard to acquire. The dead languages, too, are excluded because of the great difficulty to learn them and because of their slight adaptedness to modern conditions. Nothing remains, therefore, except to construct an international language artificially. In the report mentioned Hugo Schuchardt expresses these ideas in the following clear way:

> The adoption of a living language, not to speak of the imperfections inherent in all our languages, would engender an intolerable inequality between the nation whose language would be selected and all the other nations and would threaten the latter with utter denationalization. On the other hand, none of the dead languages can be recommended because of the difficulty to learn them. The only alternative is the adoption of an artificial language.

The objections against an artificial language are refuted by the great scholar as follows:

> The chief objection raised against an artificial language is that a language is an organism comparable to the human body, an artificial language therefore impossible like the homunculus. Language, however, is no organism, but rather a function, a social activity.

The learned professor continues here with a beautiful simile:

> An ancient city irregularly built or half in ruins furnishes the best motives to the painter and the most vivid inspirations to the poet. Will they prevent the historian from reconstructing, cold-bloodedly, the past of that city? And will all three object to the architect building a new city in conformity with the exigencies of traffic and hygiene? If the homunculus objection opposes the natural to the artificial, this is of no importance in practice. Do we not often replace, with the greatest success, natural productions and actions with artificial ones? Besides, the opposition of the natural to the artificial does not exist at all in the domain of language. The artificial languages are more or less

natural and the natural ones are more or less artificial. The artificial in our languages is especially extensive in the written languages. We can not place, therefore, an artificial language in radical opposition to a natural one. The tissue is the same in both, only the thread differs. Here it is finer, more entangled, there it is coarser, more simple. The sentimental and intellectual values of a natural language are real, but they do not lie in the language, but in our relations to it, not in the instrument, but in the manner we are accustomed to make use of it. Like Antaeus in contact with the earth so also can every one display his whole force only in his mother tongue. In comparison with it all other languages, natural as well as artificial ones, are cast into the shadow. It is true, with a foreign language one assimilates an essential part of the culture herein embodied. But that anybody could express his thoughts on the highest questions in two or three foreign languages with as much clearness and ingenuity, as much surety and ease as in his mother tongue, such a thing has never yet been observed. Be this as it may, experience has taught that whatever can be said in a natural intermediary language can just as well and even better be expressed in an artificial language.

These views agree completely with the judgment of another great linguist, Max Müller, who states that an artificial language is not only possible, but could even be more perfect, more regular, and more easy to learn than any natural language.

Some knowledge of the history of the attempts to create a universal language is indispensable for the proper appreciation of the problem of an auxiliary international language. Before presenting this historical review it must be expressly stated that no language inventor worthy of mention has pursued the aim of curtailing in any way the natural languages, least of all to replace them entirely by his project. This is especially to be emphasized because the erroneous impression prevails with the public that the advocates of an international language wish to abolish the natural languages. A similar notion may have been harbored by some visionaries, but has been far from the thoughts of all experts on the problem and of all language inventors. They merely strove to create an auxiliary language for all occasions of an international character. Some philosophers, it is true, were convinced that it was possible to construct artificially a language more perfect than any of the natural languages, but they did not want to retrench the latter on that account. This more perfect language was sought by them merely as an auxiliary language.

A universal language is first mentioned in the Bible:[2] "And the whole earth was of one language and one speech." In the same chapter the origin of the diversity of language is explained thus: "Go to, let us go down and confound their language that they may not understand one another's speech." In the prophet Zephania occurs this passage (III, 9): "For then I will turn to the nations

[2] Genesis XI, 1.

a pure language that they may call upon the name of the Lord to serve him with one consent." Some believe that in these words is expressed the desire for a common language for all nations. But this view is open to doubt.

As far as can be ascertained the idea of a universal language does not come up distinctly before the end of the 16th century. At that period new pathfinders arose in philosophy, introducing a new philosophical era. Some of those geniuses deemed the natural languages cumbersome and inadequate for the expression of logical reasoning because of their insufficiencies, ambiguities and illogicalities. The construction of a commensurate, logical and easy language for philosophy appeared to them expedient and feasible.

Theoretical views on a universal language are found in the works of Francis Bacon. The father of modern philosophy, Descartes, went further. In a letter dated Nov. 20, 1629, to P. Marsenne, he outlined a plan for a universal language. He postulated for it complete regularity and the possibility of understanding the language by the mere medium of a dictionary. The great mathematician and philosopher Leibnitz entertained the idea of a universal language throughout his career. He put up definite requirements for its grammar and vocabulary and offered a complete project. He never wrote a special work on a universal language, but numerous texts relating to his project are scattered throughout writings of his which are still inedited to a large extent.

Complete artificial systems of language had not been published before the first half of the 17th century. New devices appeared from time to time until our very days. About 250 systems have been constructed during this 300 years' period. In 1903, the French philosopher and mathematician, Dr. Louis Couturat, the able investigator of Leibnitz and the greatest authority on our problem, in conjunction with Dr. L. Leau, published an extensive volume on the history of the universal language, "Histoire de la Langue Universelle." The authors of this excellent work very appropriately divide the systems devised until then into three classes:

(1) Systems a priori. They disregard completely the natural languages and create their elements, *i.e.*, words and affixes, entirely anew and arbitrarily.

(2) Mixed Systems. They obtain their elements by borrowing some from the natural languages and by building others anew and arbitrarily.

(3) Systems a posteriori. They derive almost all their elements from the natural languages.

The systems a priori are the earliest ones, but some of them have

appeared even later than the more developed mixed devices and the most advanced systems a posteriori.

Systems a priori

The first a priori systems were the so-called pasigraphies, *i.e.*, languages fit only for writing. Early pasigraphies are those of Bishop John Wilkins (1641) and of the Marquis of Worcester. Two later pasigraphies have obtained practical application and official recognition, the International Code of Maritime Signs adopted in 1864 and the Bibliographical Decimal Classification proposed in 1873 by Melvil Dewey, president of the Association of American Librarians.

To the pasigraphies may be counted the mimic language set forth as universal language by some authors, notably Jean Rambosson in 1853.

Also the first devices intended for speech were a priori systems. Noteworthy is the so-called musical language or Solresol devised by the Frenchman Jean François Sydré in 1817. It is built out of the seven monosyllabic names of the gamut tones. Men like Victor Hugo, Lamartine, Alexander v. Humboldt were great admirers of the system. It gained many adherents in France and England.

The principal fault of the a priori systems is great difficulty. On one hand their elements are entirely new, on the other hand the devices have mostly a philosophic basis, being founded upon a logical classification of the ideas, upon a complete analysis of all knowledge. Besides, such a classification is bound up with the progress of science. A language depending upon this progress would often have to undergo radical changes. Owing to these two faults the a priori systems have not acquired general recognition.

Mixed Systems

The mixed systems, however, had a remarkable success. They comprise Volapük and its derivatives. Twenty years before its appearance the famous philologist, Jacob von Grimm, had published a project for a universal language which belongs in the same class because it contains features a priori, although on the whole it is constructed a posteriori. Excellent conditions for a universal language are prescribed in this project:

(1) The universal language must be rigorously logical, *i.e.*, every word must have an unequivocal meaning and the formation of words by derivation and composition must be accomplished in conformity with fixed rules. The author adds this pertinent remark, "If the universal language did nothing else but remedy the

confusion of ideas produced in all our languages by the vague meaning of so many words, the trouble would be amply repaid."

(2) The universal language must be of unlimited richness.

(3) The universal language must have a harmonious sound like Italian, Hungarian or Turkish.

(4) The universal language must be extremely easy to learn, to write and to speak.

This excellent project is greatly impaired through an a priori feature which entirely nullifies the fourth requirement.

The main representative of the mixed systems is Volapük. It was invented by the German priest, Johann Martin Schleier, of Constanz Baden, and published in 1880. It spread rapidly in all civilized countries. In 1889 the number of those practicing Volapük was estimated at one million. A great many books and periodicals in and about Volapük were published. In 1889 the third congress of Volapükists took place in Paris and was attended by numerous delegates from all parts of the globe who spoke Volapük exclusively. Its triumph seemed to be final. But in the same year began its decline, which was more rapid than its ascent. Shortcomings of the language were discussed at the congress, but no agreement about the necessary reforms could be achieved. This became fatal to Volapük. From 1889 the propaganda for the language became slack and soon it ceased almost entirely. In 1893 the Academy for Volapük made a clean sweep of the language by devising an entirely different one, called Idiom Neutral. Volapük soon passed into history.

Volapük has two radical faults: The vocabulary is not international and the grammar is too synthetic in contrast with the modern languages which more and more tend to analytic construction. National words are frequently corrupted beyond recognition. No English-speaking person could recognize the expression "world speech" in the word "Volapük." These two chief faults and others, as inconsistency in the derivation of words and the application of idiotisms, particularly German ones, render the language very difficult. Besides, it lacks euphony, containing various sounds that are hard to pronounce.

Volapük has the inestimable merit of having furnished for the first time the experimental proof on a large scale that an artificial language for writing and speaking is possible.

Other mixed systems, as the Blue Language (Léon Bollack, 1899), etc., have had no practical application.

Systems a posteriori

The construction of artificial languages is much further developed in the a posteriori systems. Worthy to be mentioned are Nov

Latin[3] and Idiom Neutral.[4] The American Philosophical Society, in 1888, published a plan for an international language which has been realized in the best a posteriori systems.

Of these only one has obtained general recognition and practical application, Esperanto. The latter represents the second successful experiment, on a large scale, of the possibility of an artificial language and comes near Volapük in regard to practical success. It was published in 1887 by the Russian physician Dr. L. L. Zamenhof, of Warsaw. Until 1896 it had not acquired any noticeable propagation. In that year the Frenchman, Marquis L. de Beaufront, began to take interest in Esperanto. He published textbooks, dictionaries and a large Esperanto magazine. Thereupon the language spread rapidly in France and all other countries. In 1903 the number of those practicing Esperanto was estimated at 50,000 in all countries. This number increased in the next three years to a very great extent. In the United States Esperanto was almost unknown until 1905. In this year the writer became acquainted with Esperanto and after long search he succeeded in finding in New York City half a dozen people who knew something about the language. With their help he founded the New York Esperanto Society. Soon afterwards he published the first complete English text-book of Esperanto. These two events were reported prominently in magazines and daily papers. This directed the attention of the public to Esperanto, and soon Esperanto clubs were formed in several large cities of the United States.

But great practical success of an artificial language may be only transitory, as we have seen with Volapük. Indeed, its history is repeating itself in Esperanto, only at a slower pace. Competent students of the problem saw the substantial defects of Esperanto right from the start and pointed them out. Yet they advocated it because of its good features and because its faults seemed to be capable of correction.

The opportunity for introducing the necessary reforms came in the fall of 1907. At that time the International Delegation for the Adoption of an Auxiliary International Language, founded by the International Association of Academies in 1900, convened in Paris for the purpose of fulfilling its mission. A committee of the delegation composed of scholars of international reputation examined many artificial languages and found them all unfit for the rôle of an international language, including Esperanto. The committee recommended a system presented to it for examination by an author

[3] Dr. D. Rosa, 1890.

[4] Volapük Academy, M. Woldemar Rosenberger, 1902.

under the pseudonym Ido whose identity was then unknown. The wording of the committee's decision to this effect was composed in a form favorable to Esperanto in order to win over the great number of those putting implicit confidence in Esperanto. The decision reads, "The Committee has decided to adopt Esperanto in principle under reserve of certain modifications to be executed in the sense of the project of Ido." Any other a posteriori system modified in that sense would have given the same result; for these systems resemble each other a great deal. It is entirely erroneous to call the new language simplified Esperanto. One might, with more justice, call it simplified Idiom Neutral, Nov Latin, etc. The vocabulary is the chief part of a language, and in this respect the new language of the delegation stands much nearer to the devices just mentioned than to Esperanto, which violates the a posteriori principle extensively. Grammatically, the new language has in common with Esperanto nothing but seven of the so-called grammatical endings and a few suffixes. The idea of using grammatical endings is not even original with Esperanto, but already contained in much earlier systems,[5] and even the same grammatical endings as those of Esperanto are found in these systems.

The committee of the delegation recommended an understanding with the International Esperanto Committee of which the writer was also a member. A permanent commission for the perfection of the project of Ido was formed, and the committee of the delegation adjourned.

The permanent commission had no success in trying to bring about the understanding with the Esperanto Committee. The pretended majority of the latter positively refused to recognize the necessity of reforming Esperanto. From now on the dogma, demanded already previously by influential Esperantists, that the language is inviolable and not subject to criticism became firmly established. The degeneration of Esperanto through its intrinsic faults continued now without restraint since the most capable adherents gave it up, turning their attention to the project of Ido.

A comparative estimate of Esperanto and Ido will be more clearly understood by an exposition of the requirements and principles indispensable for a logical international language (IL). The vocabulary of the latter must be based upon the principle of the maximum of internationality and the a posteriori principle: the words of the IL must be as much as possible international, *i.e.*, common to the principal living languages; a conception for which no international word exists is not to be expressed by a word arbi-

[5] "Langue universelle," by Faguet, 1765; "Pantos-Dimou Glossa," by Rudelle, 1858; "Weltsprache," by Eichhorn, 1887.

trarily invented, but by one taken from some natural language living or dead (national words). The vocabulary of the IL will therefore consist partly of international, partly of national words. The objection that this lack of uniformity would impair the IL is refuted by the most efficient and most expressive language, English, which is composite to a very great extent.

The principle of internationality does not apply to the races who have been backward in civilization for thousands of years. Their idioms are undeveloped and foreign to the languages of the races who have been the bearers of civilization. A combination of the two would be a repugnant mixture, like Pidgin-English.

Those who speak of Chinese as the IL to be selected, at least partly, do not consider that the 400 millions of the celestial empire do not speak one language. Even the words of the dialect most diffused in China are unfit for the IL because they are pronounced with a certain musical tone which is as important for the meaning of a word as its consonants and vowels. If the words were adopted without their tonal character, they would be unrecognizable to the natives and the IL would abound in ambiguities.

The words of the IL must be phonetic, *i.e.*, every letter or letter combination is to be pronounced always in the same way.

Euphony, too, is an important requirement of the IL. Its sound must be pleasing. This excludes letters or letter combinations hard to pronounce.

The preceding two requirements necessitate slight changes of a posteriori words, for instance, the replacement of the sign ph by the sign f, or of the sign c by the sign k whenever the former has the sound k; or the omission of s or x before c, as in the roots scienc, excit, which have to be changed into cienc, ecit. Actual mutilations of a posteriori words, however, must never take place. There is no justification for deforming the English word "speak" into "pük" (Volapük), or the roots "cerebral," "frontal," etc., into "cerb," "frunt," etc. (Esperanto).

The words discussed so far are original or root words. Other words are obtained from these by derivation. One of the cornerstones of a logical language is regularity of derivation. The latter is intimately bound up with the grammatical constitution of a language. A preliminary short description of the elementary grammar of the IL is therefore requisite for an exposition of derivation. The grammar of the IL must be of utmost simplicity, reduced to a minimum. If possible, a given text should be intelligible at the first glance as far as grammar is concerned. There is only one means to accomplish this; it consists in making the main parts of speech recognizable by invariable characteristic endings. For the

verb (infinitive), substantive, adjective and adverb these endings are respectively -ar, -o, -a, and -e. These endings are called grammatical endings because they show at once the grammatical rôle of every word in a sentence. They have no meanings by themselves, which is a very important point in derivation.

We can now take up derivation. One word is transformed into another one, for instance, a verb into a substantive, by changing the grammatical ending. This transformation is called the immediate derivation because no new element of idea has intervened between the derivative and the original, both expressing essentially the same idea under a different grammatical rôle. The derivative does not contain an idea not contained in the original.

Sometimes an additional idea, *i.e.*, one not contained in the original, is to be imparted to the derivative. This form of derivation can evidently be accomplished only through affixes which have meanings by themselves. This mode of building new words from given ones is called mediate derivation, because the derivative is obtained from the original by the intervening of an additional idea indicated by an additional formal element in the derivative.

The meanings of all derivatives are determined by several principles. The fundamental principle for a logical language is the principle of unambiguity propounded by Professor Wilhelm Ostwald: every element of a word, as root and affix, must have but one invariable sense which it must retain in all combinations it may enter into—one sign . . . one invariable sense. The writer has amplified this principle as follows:[6] Every formal element of a word must be represented by an element of idea in the meaning of the word; further, no formal element of a word consisting of several elements may lose its meaning. It follows that the meaning of a word composed of several elements must contain the meanings of all of them, but no other idea.

The meaning of a mediate derivative can now be determined very easily. It is composite, it consists of the meaning of the original and that of the affix.

As to the immediate derivatives it is to be borne in mind that, as a rule, the sense of a word is contained in its root alone.[7] A root is transformed into a word by adding a grammatical ending. The primary word formed from a root is the one corresponding to the sense of the root. Thus the primary word derived from the root mov is the verb mov-ar = to move; from the root pal the adjective pal-a = pale. Secondary words are formed from primary ones by changing the grammatical endings of the latter.

[6] Filologiala Temi, p. 14.

[7] Fil. Tem., pp. 12, 49, 53.

The meanings of secondary words are determined by the inherent relations between the various parts of speech.[8] One such relation may be explained here. The relation between the verb and the substantive derived from it immediately is that the latter signifies: act expressed by the verb; for instance, divid-ar = to divide; divid-o = division, act of dividing.

The correctness of a derivation can be tested by what may be called "the principle of the additional idea": every additional idea (idea not contained in the original) in the meaning of a derived word requires an additional formal element in the word. For instance, natur-o = nature; suffix -al = relating to; natural-a = relating to nature, natural. This derivation is correct: the derivative contains the additional idea "relating to," which is represented by an additional formal element, the suffix -al. But it is wrong to derive a verb arm-ar with the meaning "to provide with a weapon, arm", "to arm", (from the noun arm-o = weapon, arm), for the idea "to provide with" is not contained in the original and there is no formal element in the derivative to express this additional idea.

Another adequate test is furnished by the following principle:[9] Logical derivation requires that a word of the original meaning be obtained in passing back from the derived form to the original one. This follows from the principle of unambiguity. For a derivative is obtained by changing the form of an original. When the latter is restored, the original meaning must be restored, too, since the same form must always have the same sense. The following example will elucidate this. It is wrong to derive a verb sal-ar with the meaning "to provide with salt", "to salt", from the noun sal-o = salt. For if we go back from the verb sal-ar = to salt, to the noun sal-o, the latter must now signify: act of salting (see above). The same form sal-o would thus mean once: the salt, another time: the act of salting. This violates the principle of unambiguity. The derivation is wrong because the original sense is not obtained in passing back from the derived form to the original one.

The meanings of composed words are determined by several principles as the writer has shown in a special essay on composition.[10]

We are now better prepared for a review of Esperanto. This system fulfils none of the above requirements and principles.

[8] See "Logical shape of the AIL," American Medicine, August, 1923.

[9] The writer's modification of Couturat's principle of reversibility, "Étude sur la Dérivation," p. 7.

[10] Filol. Tem., Nro. 1.

(I) Infringement of the principle of internationality and of the a posteriori principle is so extensive in Esperanto's vocabulary that it would be more justified to range this device among the mixed systems than among the a posteriori ones. Of the 2629 root words of the vocabulary 1055 violate more or less the principle of internationality[11] and the most frequently occurring words are entirely arbitrary so that Esperanto texts are unintelligible without a dictionary even to expert linguists who understand real a posteriori systems almost at first sight.

(II) Esperanto has no regular system of derivation and therefore it abounds in irregularities and absurd derivatives. Numerous examples to that effect are given in Couturat's excellent monograph, "Étude sur la Dérivation en Esperanto" and de Beaufront's *Bulletin Français-Ido.*

(III) The grammar of Esperanto is so complicated that Esperantists, especially the English and French ones, are unable to write the language correctly as the writer could see from his extensive Esperanto correspondence. The modern languages have restricted the accusative to very few instances. Esperanto has made the obligatory accusative more frequent than the ancient languages. The declension of the adjective according to case and number is another great difficulty and entirely unnecessary as proved by the example of the English language.

(IV) The sound of Esperanto is often repugnant, due to extreme frequency of the sibilants, to almost unpronounceable letter combinations, and to the constant repetition of the syllables aj, ej, oj, uj, ajn, ojn, ujn. Sentences of everyday life often sound like these far-fetched English sentences: "Chichester church stands in Chichester churchyard." "Does she chew chicken giblets?" Here are ordinary sentences which have in Esperanto the same displeasing sound as those far-fetched ones in English: "Chu ci scias chiujn ciajn hodiauajn taskojn?" = (mother to her child) "Do you know all your lessons of to-day?" "Chu shi sciighis chion?" = "Has she learned (been apprised of) everything?" The syllables aj, oj, uj, etc., occur in 30–40 per cent. of the words in some of the best Esperanto writings, as in the following sentences by Dr. Zamenhof himself: "Shi havis la plej graciajn malgrandajn blankajn piedetojn, kiujn bela knabino nur povas havi" = "She had the most graceful little white feet which a beautiful girl could ever have"; "Shi envolvis sin en siajn densajn longajn harojn" = "She wrapped herself up in her thick long hair."

(V) Esperanto has a scanty vocabulary. The completest dictionaries contain only 2629 root words. The Esperantists try to

[11] *Bullet. Français-Ido,* p. 152.

persuade themselves and the whole world—and this appears quite plausible to the unthinking—that a language is so much easier the less root words it possesses. This is a great fallacy, just the opposite being true, as the writer has pointed out in an essay entitled: "How many words are needed?"[12] When the international language does not possess a one-word translation for a conception translatable with one word in a natural language, a writer belonging to the latter has to apply the means of derivation, composition or of periphrasis for expressing that conception, a task that is often very difficult and can be accomplished satisfactorily only by a competent linguist. The poverty of the Esperanto vocabulary has been productive of many absurd word compositions. Having no word for "bull," Esperanto expresses this conception by the composition "bovoviro" which logically can mean only "beef man", a man who is a beef. (bovo = beef; viro = man).

(VI) The alphabet of Esperanto contains five accentuated letters not contained in any natural language. The printing of Esperanto works is therefore difficult and expensive, which the writer has experienced in the publication of his Esperanto text-book in 1906.

An artificial language with the dogma of inviolability interdicting every criticism is as little capable of improvement as a natural language. But the weak sides of the latter often represent its nicest features; they reveal peculiarities in a nation's way of thinking. This consideration does not apply in an artificial language and therefore logical incompatibilities can nowise be justified. An artificial language can and must be perfected more and more. Indeed it is just this possibility that has induced many a thinker to concern himself with the question of an artificial language.

The permanent commission of the delegation acted in this sense after assuming the task of developing the project of Ido. It founded an academy and an official magazine, called *Progreso,* and expressly invited general criticism to be published in the latter or submitted to the academy.

It became known later that the project adopted by the committee of the delegation was the work of Marquis L. de Beaufront, the most able of all Esperantists including Dr. Zamenhof. His pseudonym Ido was subsequently adopted as the name of the language which previously had been called Ilo ("Ido" means in Esperanto "offspring"; the root "Il" is built from the initial letters of "internaciona" and "linguo").

Through strictly scientific work lasting for seven years the academy has amplified and perfected Ido considerably. It has, for

[12] *Progr.*, IV, p. 139.

instance, increased the original vocabulary of approximately 3000 root words to nearly 11,000 root words. In 1914 a period of stability of ten years was decreed excluding any further changes during this time. There are only a few important linguistic points which the academy will yet have to consider and settle. Their final adjustment will not produce any noticeable change in the shape of the language arrived at so far.

Two important points distinguish Ido from all its predecessors. Every one of them, Idiom Neutral excepted in a measure, was the creation of one author who, as a rule, was not even a competent philologist. He remained the proprietor of his work and his personal influence was decisive in its further development. Moreover, all previous systems are lacking the principles essential to a logical language which have been discussed above. These principles were unknown before. They have been clearly exposed for the first time by Dr. L. Couturat, the greatest authority on our problem, between 1903 and 1908 in various publications, notably in his excellent monograph "Étude sur la Dérivation" which appeared in the beginning of 1907. In its first edition only a limited number of copies had been printed for distribution among some known students of the problem. The writer had the honor of being one of the recipients. Those principles had been applied in Ido, which was published in the fall of 1907. Furthermore, Ido went over into the custody of the permanent commission shortly after its publication and its perfection was accomplished by an academy consisting of ten competent linguists and advised by some painstaking students of the problem. The predominant influence of one man is therefore absent in Ido.

The characterization of Ido may be summed up in the statement that it conforms to the principles and requirements for a logical IL set forth above. This may be somewhat particularized to contrast Ido with Esperanto more clearly.

(I) There is no arbitrary word in Ido. All its words are a posteriori, *i.e.*, taken from the natural languages. A less international word has sometimes been selected instead of a more international one for valid reasons. Thus the word "hund-o" (= dog, Engl., Germ.) has been adopted instead of the more international word "kan-o" because the latter is needed for the conception "cane". Slight changes of a posteriori words have been made to comply with phonetics and euphony. Thus, the roots "scienc" and "excit" are changed into "cienc" and "ecit", because it is very hard to pronounce the former phonetically.

(II) Strict observance of the principle of unambiguity and that of the restoration of the original sense in restoring the original form

(principle of reversibility) regularize derivation in Ido. The same rule applied in corresponding instances leads to corresponding results whenever new words are derived from given ones.

(III) The entire elementary grammar of Ido is contained in this one simple rule: The main parts of speech are recognizable by 14 characteristic endings. The latter indicate at once the grammatical rôle of every word in a sentence and this is all that is needed to understand a given text in any language as far as grammar is concerned. Indeed, one familiar with two or three European languages can understand a given Ido text even without a dictionary. Besides those fourteen endings he needs to know only the definitions of a few affixes. The adjective in Ido is invariable and the accusative is restricted to the very few cases where it is indispensable to avoid ambiguities. The syntactical rules of grammar are only those required by general logic and common to all well-developed natural languages.

Some object even to this minimum of grammar. They would want the IL to consist of words never inflected. Indeed, there are natural idioms of that character. The very young child does not use inflected words in his talk. A similar phenomenon may be observed in several spontaneous international dialects, such as the Lingua Franca prevalent on the Mediterranean coast, Chinook in the region of the Columbia river, and Pidgin-English on the Chinese coast. Such jargons may be sufficient for expressing the crude thoughts of young children or of adults devoid of any education. But it is a preposterous notion that an IL patterned after those jargons would be adequate to express ideas of Homer, Aristotle, Shakespeare, Newton, Darwin, Goethe, Spinoza, Einstein. The AIL is intended chiefly for making the productions of such geniuses readily accessible to all nations.

(IV) Ido equals Italian with regard to euphony. Of this one may convince himself by reading aloud Ido texts.[13]

(V) Ido has a rich vocabulary of over 11,000 root words and its further enlargement is not limited. The academy is adopting more and more words on the recommendation of competent students who use the language exclusively for scientific works and translations from the natural languages and thereby chance upon conceptions requiring integral (root) words for their expression. The writer entertains the opinion that an author may even render a conception for which the Ido vocabulary has no adequate translation by a word that is neither official, nor semiofficial, *i.e.*, publicly proposed and under consideration, if only that word conforms to the principle of maximum of internationality, or to the a posteriori

[13] See "Comparative texts," Ido, pp. 12–16.

principle when there is no international word for the conception, and provided he indicates in some manner that the word is of his own selection.[14]

(VI) Ido employs the Anglo-Latin alphabet and thus fulfils the requirement that the alphabet of the IL should be simple and not contain any letters with diacritic marks.

Ido can be improved, its further perfection relating chiefly to two points, to the determination of the logical meanings of composed words and some derivatives and to the enlargement of the vocabulary. Regarding the first one two questions remain to be settled: (1) Which is the logical meaning of the substantive derived immediately from an adjective? (2) Which is the logical meaning of a composed word?

The first question has been extensively debated in Progreso by Dr. Couturat and the writer, but is still undecided. The second question is treated by the writer in a long essay where he believes to have proved that certain views advanced by Couturat and another great authority are untenable. The two questions are of general philological interest and their exact solution is of great importance for the perfection of the IL. The final decision regarding them, however, will produce no noticeable change in the shape of Ido arrived at so far.

The vocabulary of Ido can and should be made so rich that the language should have a one-word expression for every conception which can be expressed with one word in any of the principal European languages. This is the writer's answer to the question: "How many words are needed?" (*Progr.*, IV, 139). Only such a vocabulary would impart true facility to the IL. The objection that the student would have to learn too many words is not valid. The English student does not need to know all the words given in the Standard Dictionary.

A most important question pertaining to our problem is this one: Does Ido represent the final solution of the problem of the AIL? Unless this question can be affirmatively answered, students will not concern themselves with Ido when they learn from the history of the problem that so many previous devices have failed. The answer results from the following considerations. The original words of the IL are not dependent upon the ingenuity of the inventor of a new system, but predetermined through the principle of maximum of internationality and the a posteriori principle. Indeed, all the systems a posteriori resemble each other a great deal with respect to the root words. The differences between them are due to those principles not having been carried through with equal

[14] *Progr.*, IV, 139; Raporti al Idoakademio, Nro. VI; Filol. Tem., Nro. V.

strictness in the various projects. Any future device that will apply them exactly will contain the same root words as Ido. Only a few national words may differ. The composed words are given in their forms and logical deductions determine their meanings. The latter do, therefore, not depend upon the arbitrary decisions of authors.

The immediate derivatives in the supposedly new system must be analogous to those of Ido. For the rules of immediate derivation are founded upon the principle of unambiguity, upon its corollary, the principle of reversibility (restoration of the original sense in restoring the original form), and upon the relations between the various parts of speech. These relations can not be arbitrarily invented, nor defined in different ways since they are inherent in the parts of speech. The rules of immediate derivation are, therefore, not free, but predetermined.

The mediate derivation is accomplished through special affixes. The choice of the latter is free, *i.e.*, the affixes are more or less arbitrary. An affix, however, applied in a given case, can only be a synonym of an affix used in Ido. Since every affix can have but one meaning according to the principle of unambiguity and there is no synonymity between the Ido affixes, the latter can only be increased, but not decreased. For in the second case two ideas distinct and to be distinguished would be fused.

The grammar of the new hypothetical system can hardly be made more simple than the Ido grammar which is reduced to one short rule.

The above considerations lead to the following conclusions under the supposition that the principles of unambiguity and of maximum of internationality are decisive factors for a logical international language. Any system fulfilling the requirements of logic and internationality that may be devised in the future can differ but little from Ido in grammatical respect. It must be almost identical with it in the original, composed, and immediately derived words. Regarding the mediate derivatives it may differ from Ido only through few different affixes. For the majority of the Ido affixes, too, are determined by the principle of internationality. Moreover, the new system may be more complete through the adoption of more affixes than are contained in Ido. An essential difference will therefore not ensue also with regard to the mediate derivatives. Ido, therefore, represents the final solution of the problem of the auxiliary international language.

The need of an AIL is now more urgent than ever. The recent great struggle of the nations has torn asunder three vast empires in each one of which a great language was used by all inhabitants.

These empires are now split up in many independent nationalities each intent upon maintaining its own language in opposition not only to the languages of its small neighbors but also to those of the great nations. Each of the latter, on the other hand, hates the other more than ever and disdains its dearest possession, its language. A neutral auxiliary language will benefit the small nationalities and will relieve the great hostile nations from the necessity of having to employ in their unavoidable intercourse languages that they despise. When true general peace will again prevail in the world, the same language which has served the enemies in their necessary transactions will enable the friends to understand one another properly in all affairs of mutual interest.

CALORIES AND VITAMINES

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THE slogan during the strenuous days of the Great War that calories would win it was true in more senses than one. For those at home, it was intended to constrain in the use of food whose value was measured in calories. Neither before nor since that time has the fact been so forcibly taught us. We forgot about pounds and pecks in the enthusiasm aroused over calories. To the armies in the field, however, calories were even more important, not only in furnishing the energy by which the individual could dig into the soil, or charge up earthworks or actually overcome his opponent in hand-to-hand struggle, but also to furnish the propelling force of bullets, the bursting power of shells, and the propelling power of motor trucks and aeroplanes. The energy of explosives like dynamite and fuels like gasoline and coal is measured by the same unit. All along the battle fronts calories were dissipated with prodigal freedom. And the power represented by the calories of food, explosives and fuels won the day. These all-important calories are units equivalent to the quantity of heat necessary to raise the temperature of a kilogram of water one degree centigrade, or roughly a little over a quart of water a degree. The physicists a number of years ago found by experiment that there is a constant relation between the work which a machine does and the heat liberated. There was established the mechanical equivalent of heat: that is, a calorie is able to lift a given weight a definite distance. As calculated by Joule, who investigated the subject first in 1840, a pound weight falling 772 feet raises the temperature of a pound of water one degree Fahrenheit. It is thus evident that these same calories furnish most convenient units for measuring both heat and energy, one calorie being equivalent to 772 foot-pounds.

But while the demand for calories and still more calories was more insistent during the war when an eager and ruthless enemy was at hand, still the demand for calories has confronted man from the beginning and promises to do so through all future ages, for without them man can do no work. He becomes in fact as inert as a corpse. Indeed there is every indication that as populations increase and arable land decreases and the fertility of the soil is gradually washed off into the sea, the problem of supplying the human engine with energy will become more pressing.

Of course, for ages before any of the refinements of calories or chemistry were recognized, our early ancestors cared in their search for food only for a feeling of satiety and the absence of an obvious pain or distress after eating, and painful experience at a very early period of human evolution must have taught them the difference between noxious and beneficial foods. A large store of knowledge regarding these properties of foods must have been acquired through the course of ages and the beginnings of the science of food selection must have been made. But of these unsystematic experiences we are not here concerned in the least. In our discussion of calories and vitamines we will attend only to the scientific discoveries which have added to our knowledge of the true value of foods and the parts which different foods play in the economy of the body.

The first important step in the scientific study of human nutrition was made by Lavoisier in the latter third of the eighteenth century when he showed that the animal heat of the living body was produced by a slow combustion, just as the heat of the candle flame is produced by the rapid combination of the tallow and oxygen, or the heat of the fire is the result of the rapid union of the fuel and the oxygen of the air. It was not till 1894, over a hundred years after Lavoisier, that Rübner with a refined technique and greatly extended knowledge of chemistry and physiology was able to demonstrate that the calories produced by the living animal and manifest as animal heat were equivalent to what might be obtained by the oxidation of the foods consumed. Following Rübner's lead, W. O. Atwater, of Wesleyan University, about 1900 made very important advances by experiments on human beings. The subjects were kept for several days in a closed chamber with elaborate devices for ventilation and temperature regulation and measurement known as a respiration calorimeter. There were also arrangements by which the air entering and leaving the chamber could be sampled. It was provided with a folding bed and a stationary bicycle on which necessary exercise could be taken. The results of many experiments covering several successive days and under different conditions of activity and with different diets, indicated so close a correspondence between the calculated energy of the food consumed, reckoned in calories, and the actual heat given off as to permit the generalization that the income and outgo of energy in the human body are exactly equal when due allowance is made for stores of energy present in the body and indicated by changes in body weight, and that the human body is as truly an engine for transforming the energy of food into heat and motion as the gasoline engine is for the transformation of the energy in the gasoline into heat and motion.

Such experiments as these of Atwater and his associates, based upon observations extending over a number of days and with full grown subjects, naturally emphasized the energy needs of the body and the fuel value of different foods. They also showed clearly by the analysis of the outgo of the subject during the period of observation the needs of the body in respect to the chemical elements, especially carbon and nitrogen, since these are needed in large quantities and from the economic point of view are the most important. With experiments of this kind in mind dietitians naturally sought to furnish diets which met these requirements in respect to calories and carbon and nitrogen. Some foods might be harder to digest and place a greater burden on the intestinal tract to handle them properly, but except for the digestibility of foods it was reckoned that one kind of protein, for example, or one fat was as good as another to meet the bodily needs. The demand of the body for energy which can be introduced only in the form of calories in the food is of course the most insistent demand of the body, for every heart beat and every movement of the smallest muscle means the burning up of some small quantity of living substance which has to be made good if the body is not to waste away. The foods differ from ordinary fuels in one very important respect in that they supply not only energy but also the very materials of which the body is made up and which are discharged from moment to moment as waste products in the excretions.

The most difficult element to supply to the body is nitrogen which can be furnished in only one form and that is, the proteins which are expensive from the economic point of view as well as the physiological, for the excretion of nitrogenous waste places special burdens on the kidneys. Fortunately the nitrogen excretion does not increase at the same rate as the carbon excretion when the activity of the body is increased. It is "protected" as it were so that it is not burned up with the same facility that some other portion of the living substance is which contains no nitrogen.

Specifically, the experiments of Atwater showed that the human body could be maintained in equilibrium with approximately 100 grams per day of protein (such as the curd of milk or the white of egg or the lean of meat) to supply the nitrogenous wastes, and the fuel value of the entire diet must be approximately 2500 calories for a man of average size leading a very sedentary life, or 5000 calories for a lumberman in the northern woods. In making up a practical diet in order that it may contain sufficient energy, or calories, the protein is supplemented by carbohydrates, like sugar and starch and fats, for although the body derives energy from the proteins and could be maintained indefinitely on such a one-sided

diet, it would not be economical or wholesome. Standard diets were calculated for men engaged in different occupations and including various combinations of food. At light work an average man would thus have his nitrogenous and caloric needs met by a diet consisting of 100 grams of protein, yielding 400 calories, 100 grams of fats yielding 900 calories, and 500 grams of carbohydrates yielding 2000 calories. Such a diet, with the usual combinations of flavorings and variety with several quarts of water (which would be mixed with the food to a great extent) and with sufficient roughage to give it bulk and decrease its concentration satisfies the appetite. It is well balanced and when obtained from natural sources, with the naturally occurring impurities and unknown constituents which defy the chemist's skill to detect, is adequate. It corresponds rather closely with what has been found by long years of experience to satisfy a normal appetite. This balancing of our diet is practiced instinctively by our preference for a little fat with our meat, for bread and butter rather than dry bread, for gravy with our potato. The combination of proteins, fats and carbohydrates just given may be regarded as a typical allowance to meet the bodily needs. In those cases where the economic conditions allow the appetite to be satisfied readily, this may be taken as a kind of standard diet. There are of course individual differences as well as racial ones, but these concern more particularly the sources of the food than the ultimate analysis of them. The Esquimau rarely partakes of carbohydrate food because of the scarcity of vegetation in the Arctic, but he makes up for this deficiency with great quantities of protein and fat which he obtains from the fish and other animal food upon which he depends. The Oriental, oppressed by poverty in a densely populated land, regards meat of the most inferior quality as a treat rarely indulged in, for carbohydrates are almost the only foods that come within reach of his constantly empty pocketbook. But Americans and Europeans, having the wealth necessary for a moderate degree of well-being, show rather insignificant variations from the normal.

Within the period covered by the experiments with the human subject in a respiration calorimeter, there were no noticeable differences in the effects of foods when due allowance was made for the approximate chemical composition. One protein seemed just as useful to supply the wastes of the body as another. Wheat bread or corn bread, meat or cheese, olive oil or butter apparently could be used indifferently. Butter, to be sure, has a certain quantity of water and salt which the olive oil does not, but when this difference was taken into account the two seemed to be equally valuable to meet the bodily needs. Corn and wheat have quite

different compositions, but the several constituents of each were supposed on the strength of these experiments to be equally valuable. In other words, up to a comparatively few years ago it was supposed that the percentage of protein, carbohydrate and fat in a given food was all that was necessary to know about it from the dietetic point of view. This view was characteristic of what we may call the dietetic age of the calorie. To be sure, it had been known for years that there were some proteins like gelatine which could not replace entirely in the diet the proteins which occur naturally in foods in various combinations. It contained nitrogen which could be used by the body and could replace to a large extent the more expensive proteins, but curiously enough animals fed on this one substance yielding nitrogen soon sickened. Long before there was very much of a science of nutrition or physiological chemistry, in the days of the French Revolution, when meat was so expensive as to be quite beyond the reach of all but the wealthy, and milk and eggs were quite as expensive as meat, the savants of the French Academy tried to substitute for meat gelatin which they manufactured cheaply from bones and tendons which were in themselves unfit for human food. This substitute was tried on hospital patients but the effects were not all that were desired. The gelatin was digested readily, and for a time seemed to satisfy the needs of the patients, but in the absence of other nitrogen-containing food they grew so uniformly sicker and sicker after a time that it became apparent that the diet was at fault. Gelatin accordingly came to be regarded as a useless addition to the diet and for a long time was most unjustly condemned. Since the French Revolution there have been other attempts to make artificial foods to take the place of the vegetables and meats and milk and eggs which mankind has lived on for so many centuries, but until very recent years they have been uniformly unsuccessful. Foods specially purified by the chemists, though not those that bear the label of the pure food law, could not take the place entirely of the foods which nature prepares in the great out-of-doors.

The failure of animals to survive long on a diet composed of chemically pure constituents rather than the mixtures of different proteins, carbohydrates and fats which are found usually in the products of the field puzzled physiologists for many years. In fact, it has only been during the last ten or fifteen years that the defects of gelatin and other semi-artificial products as foods have been accurately understood. To-day we know that few proteins singly can satisfy the nitrogenous needs of the body.

Before we leave the age of calories, however, reference must be made to the experiments conducted by Professor Chittenden at

Yale. Influenced by Horace Fletcher's propaganda on the advantages of a low protein diet, Chittenden undertook a prolonged experiment on a large scale to test the validity of the conclusions of the physiologists that at least 100 grams of protein per day are necessary to maintain the body in nitrogenous equilibrium. Is it necessary to burden the body with the disposal of so much nitrogen per day as the dietitian had supposed? Chittenden experimented with a squad of soldiers who were widely advertised in the newspapers. His results seemed to indicate that the standard diet which Americans and Europeans had adopted more or less instinctively and which had been accepted by experimenters generally would have to be revised. A dozen or more normal men during a period of six months living on a low protein diet equivalent to about one half of what was usually regarded as the minimum seemed to suffer no evil effects. He subjected them to measurements and severe physical tests at various times during the period under consideration and found that they remained in the best of condition with no appreciable loss of vigor or strength.

For a while it looked as if the quantity of protein which was habitually consumed was greatly in excess of what the body needed and that great economies could be effected both from the monetary and physiological points of view by the general adoption of the low protein diet. The calories received a boost accordingly, and the emphasis was again placed on the all-important factor of fuel value of food. In spite, however, of the vindication of the low protein proponents it is exceedingly interesting to see how slowly the new dietary régime has been accepted by the populace generally. The evils of an excessively rich protein diet were emphasized by these experiments and some rationalizing of the diet resulted, but the long established habit of a moderately rich protein diet persisted, the flesh pots clamored loudly and the appetite for the approximately 100 grams of protein a day was so insistent that it would seem to indicate a fundamental need of the body. To what may we attribute this well-established habit? Is it simply the effect of a pernicious habit which is as persistent as it is pernicious? Is it simply a manifestation of the perversity of human nature? The answer to these questions has not been forthcoming after many years. In fact, it was not until the experimenter was in a position to test the effects of single purified proteins on growing animals extending over prolonged periods that light was thrown on these problems.

The problem of the effects of single purified proteins on growth and health was taken up by the two American physiological chemists, Osborne and Mendel, at New Haven. Their purpose was to

study the effects of diets which were ample in their calories and in the quantity of the necessary chemical elements to meet the needs of the body, but which differed from each other simply in the nature of the protein which was supplied. Chemically purified proteins in place of the mixtures which occur with few exceptions in natural products were fed. In this way it was possible to determine whether one protein is as effective as another in satisfying the bodily needs. As already indicated, it had been known for a century that gelatin was incapable of taking the place of proteins entirely. What is there about the gelatin which renders it unfit to supply all the nitrogen which is needed? Is one protein as effective in preserving the nitrogen balance in the body as another? These were questions which the experimenters attempted to answer. They chose white rats as their subjects because of their convenience in the laboratory. They do not require vast quantities of food and they mature and reproduce rapidly, so that growth can be quickly determined and the effect of the restricted diet can be determined on successive generations. In these animals, the female bears her first litter when only 120 days old, and by the time she is fourteen months old may have had as many as five litters. The span of life of a well-nourished rat is about thirty-six months, so that in three years the observer can follow the course of life of an individual corresponding to a period of ninety years in the human life span!

As early as 1908, it was found that growth did not take place in the white rat with the same rapidity when single purified proteins were used exclusively in the diet, regardless of how much was fed or how abundant the diet in general might be. One rat which was given an ample diet in which the only protein was the casein of milk, supplemented with a well-balanced ration of sugar and starch and fats and inorganic salts, increased steadily in weight from 60 grams to 270 in the course of 140 days. Another rat fed on the same diet, except that one of the proteins of wheat took the place of the casein, gained only 40 grams in 240 days. Such a gain in weight over so long a period would be about the same thing as a man's gaining say 20 pounds between the ages of one year and twenty! A third rat treated similarly, except that the principal protein of corn took the place of the casein, actually lost 40 grams in less than 90 days after having been changed from a mixed protein diet to the experimental one.

Results like these showed unquestionably that calories alone were far from being the only requirements for an adequate diet, even when they were administered through foods containing the requisite quantities of protein, carbohydrate and fat, especially for a growing animal, and that far more subtle factors play a large

part in satisfying the physiological needs of the body. These experiments called attention especially to the differences in the "building stones" of which the proteins are composed—the amino-acids. These are rather complex compounds, although marvelously simple in contrast to the proteins themselves. They can be obtained from proteins by certain analytic methods which bring about their decomposition to simpler bodies.

In the chemist's shorthand method of expressing chemical composition, one of the very simplest of these amino-acids has the formula $CH_2 \cdot NH_2 \cdot COOH$, which means that it is composed of the elements carbon, hydrogen, nitrogen and oxygen in the proportions indicated by the number of atoms of each—two of carbon, five of hydrogen, one of nitrogen and two of oxygen—and that these atoms are definitely arranged so that on analysis some of them seem to be more closely held together than others. This is also indicated by the arrangement in the formula and the separation of the whole compound into three separate radicals. There are some eighteen of these amino-acids which the chemist has derived from proteins, but as they all bear quite unusual names, it is hardly necessary to enumerate them here. Their "nickname" of building stones of the proteins is in allusion to the fact that they apparently enter into the composition of the proteins like stones in a wall. The arrangement of the stones may give a particular pattern to the wall, and a selection of stones may make a wall of specific material. There is every indication that in the digestion of protein food the molecule is broken up into the separate amino-acids and in assimilation these same building stones are brought together in different patterns and in different proportions, comparable to the formation of words by combining syllables in different ways and repeating them varying numbers of times. We have to think of the building of the living substance, not like architectural construction from sand and cement and wood and iron, for example, but from elaborately shaped blocks, each of which may contain definite proportions of the elementary building materials.

This idea was confirmed by the fact that proteins which in their purity were inadequate might be made thoroughly satisfying by adding to them in the diet the amino-acids which they were lacking in their make-up.

A new factor is thus seen to enter into the problem of diet. Not only must there be a certain amount of protein furnished, but also it must yield on decomposition or digestion the necessary amino-acids. The proteins are not for this reason equally useful to the body. Some of the amino-acids are required in very small amounts to make good the wear and tear of the body while others must be

provided in much larger quantities. It is especially in the growing animal in which new material has to be constructed that the need for these particular building stones is most keenly felt, for once these structures are formed, the wear and tear does not affect them so severely. In the ordinary varied dietary, especially if there is sufficient milk, there is little danger of a deficiency of one of the necessary amino-acids. This deficiency is manifest only when the diet is very monotonous with reference to the proteins and when they lack some of the required amino-acids.

In the light of what we now know about the products of decomposition of gelatin, for example, it is evident that its failure to replace satisfactorily ordinary proteins lies in the fact that it lacks two important building stones which the body can not put together and which occur in nearly all ordinary proteins. The inadequacy of gelatin may be likened to that of a font of type in which, for example, the letters *a* and *t* are missing. The compositor may set up a few words perfectly without being aware of the imperfection of the font, but pretty certainly before much progress has been made these letters will be demanded by the copy and the work will be held up until the missing letters are furnished. As a matter of fact, experiments have shown that if the missing amino-acids supplement the gelatin, the diet is satisfactory.

It may be worth suggesting that a possible defect in the extremely low protein diet may lie in the undue reduction of the factor of safety in respect to these constituents, so that the instinct to increase the protein consumption when the supply can be procured readily may be to prevent this serious defect.

While most of the amino-acids have to be furnished to the animal body ready made, there are some relatively simple ones, like that whose formula was given above, which can apparently be manufactured directly in the body: at least, growth is not retarded when the protein diet is deficient only in regard to it. On the other hand one of the more complex amino-acids that is lacking in the protein of corn can not be built up in the body. As a result, maize, when used exclusively as a source of protein, is inadequate. The protein of milk affords an abundance of this constituent and is one of the most important promoters of growth that we know. To-day, the student of nutrition keeps in the foreground the fact that it is not nitrogen in an uncombined state that is utilized by the body, but in the complex amino-acids.

So far, however, in our discussion of diet, nothing has been said of the vitamines which within the last few years have come so strongly to the fore in the field of dietetics. The diet, to be adequate, must represent sufficient calories to supply the energy of the daily and momentary activities of the body. It must also contain

certain amino-acids in order that none of the necessary building stones out of which the complex proteins are made are lacking. And there must also be present certain bodies known as the vitamines. We still know practically nothing in regard to the composition of these bodies and only in a general way may they be said to act as regulators of chemical activity in the body without which a large number of nutritional defects very promptly put in an appearance. They were discovered more or less inadvertently in experiments designed to test the value of isolated and purified fats upon growth and nutrition.

About these regulators of metabolism we still know little, so little in fact that they have been given such equivocal names as fat-soluble A, water-soluble B, and water-soluble C. Deficiencies of these bodies in the diet lead to certain well-known diseases which yield to treatment by supplying the deficiencies. Scurvy, which caused terrific suffering in the olden days among mariners who lived exclusively for months on biscuits and salt pork, was relieved almost immediately by adding a liberal allowance of fresh meat or vegetables. Beri-beri which is a disease common among the poorest classes in the Orient whose food is principally polished rice and fish is relieved by the addition of an extract of the polishings of the rice. Pellagra is another disease brought on by a one-sided, monotonous diet which yields readily to a change of food.

Experiments in which foods purified artificially have been employed have invariably led to symptoms like certain of these deficiency diseases.

It was not till 1912 that light began to dawn on this problem of why thoroughly refined or purified food was inadequate through the work of McCollum. Rats were again the subjects for the experiments and a diet which consisted of purified casein, milk sugar, starch, fats of different kinds and mineral matter similar to that which is represented by the ash of milk was used. The proportions of these different ingredients were carefully worked out and their purity was very high. In these experiments it was observed that butter fat permitted normal growth to take place while the substitution of lard, olive oil or other vegetable oils interfered with the normal rate of growth or inhibited it altogether. In spite of the fact that the different fats fed seemed by chemical analysis to be pure, one was adequate, the others mentioned were distinctly inadequate. Three years earlier Stepp found that mice could be reared on a ration of bread made with milk, but died shortly when fed on the same bread which had been extracted with alcohol. The alcohol dissolved something out of the bread which was essential for the well-being of the animals. Incidentally it may be noted that the addition of the substances dissolved out by the alcohol to the ex-

tracted bread rendered the latter capable of supporting life as it did originally. In other words, the alcohol had removed without altering some constituent of the ration. The analysis of this extract did not disclose anything extraordinary or unexpected, but when these known substances were added to the extracted bread it remained inadequate. The only conclusion to be drawn from these results was that there must be something necessary for the support of life which is soluble in alcohol but in such small quantities as to escape detection by ordinary chemical means.

It remained for McCollum and his associates to demonstrate a constituent of butter fat or cream which is necessary for growth as well as for the maintenance of life in mice beyond a period of a few weeks. We are still unable to detect this substance chemically so that it is impossible to determine its chemical properties. It is, in fact, only by testing foods specially purified or specially separated constituents of the food on living animals for a longer or shorter period that its presence can become known. McCollum was unable to isolate this necessary regulator of the life processes but in as much as it occurred in fat, he gave it the very equivocal name of fat-soluble A, and to this day this unknown substance bears that name. So powerful is it in its action that one five-hundredth of a milligram has an easily seen effect on an animal, and this is true when in a most impure condition, for the chemist has so far been unable to isolate it in its purity.

This fat-soluble A, which is one of the few vitamines whose presence is definitely known, occurs also in that exclusive food of the developing chick, the yolk of the egg. It is abundant also in the fat that is deposited in the liver. Cod-liver oil owes its wonderful effect on growth and development to this unknown constituent. It may be substituted with impunity in the laboratory for butter. It also occurs in the leaf vegetables like spinach and lettuce. On the other hand, certain vegetable oils like olive oil and almond oil proved quite as ineffective in keeping rats healthy as did lard. This, of course, does not mean that vegetable oils and lard are improper foods or of little value. Far from it, they are very rich in heat units and satisfy hunger quite as effectively as the highly esteemed butter fats and the much despised cod-liver oil. The butter fats contain this something, fat-soluble A, in very small quantity, which regulates the metabolic activities of the body and supplies something without which the body can not survive.

McCollum found still another vitamine in his experimenting which is just as necessary for the proper maintenance of the body as the fat-soluble A. The abnormal conditions which result from prolonged feeding on polished rice and which together constitute the disease beri-beri in the human subject are not relieved by the administration of butter fat. The addition of skim milk in this

case relieved the symptoms which the butter fats failed to relieve. The milk sugar of milk was then used in place of the skim milk and as long as this was not purified too highly chemically, it served to relieve the unfavorable symptoms. The conclusion was inevitable that there was something in the skim milk necessary for health but which can not be isolated in pure form from it. To this unknown body he gave the name of water-soluble B. This substance occurs very widely distributed in natural foods. It is soluble in water so that in boiling foods it is extracted and lost if the fluid is discarded. Vegetable soups, boiled cabbage with the liquor, milk, the outer husks of cereals, and above all, yeast, are rich in water soluble B. In fact, from 200 pounds of yeast, one twelfth of an ounce of a product has been obtained which is so active in relieving the symptoms of beri-beri in pigeons that one fifteen-thousandth of an ounce has marked effect in a few hours.

This vitamine is so widely distributed that it is unnecessary to take special precaution to insure enough. It is not stored in the body against the day of need, so that small quantities must be eaten fairly constantly to keep up the vigor of the animal. It is only the over-refinement of the culinary art which dispenses with every portion of the food which is difficult to masticate or which is in the nature of "roughage," which is likely to lead to a deficiency of this compound in the diet.

A third vitamine has been demonstrated, different from the other two in its curative or corrective effects but still unknown as to its composition. It is particularly abundant in succulent vegetables and fruit in the fresh condition, especially oranges and lemons. It also occurs in milk, provided that the cattle have had a diet that was ample in this constituent. It is destroyed by heating and drying unless the material is very strongly acid; desiccated cabbage and potatoes apparently lose much of their effectiveness in relieving the symptoms of scurvy which follow a deficiency of this compound.

So far, only these three vitamines have been demonstrated. Their action seems to be quite definitely regulating, since the absence of one or the other leads very promptly to pathological conditions.

From what has just been said in regard to calories and vitamines, the outstanding conclusion is obvious, that in the long years of human evolution the appetite has become most accurate in determining the needs of the body and that the body has been most accurately adapted to the food stuffs which occur in nature and which have not been purified by artificial means. The advances in dietetics have not succeeded in reducing the complexity of the problem of supplying adequate food, but most definitely have shown that many factors previously unknown are essential to the maintenance of health and vigor.

OCEAN LIFE

By Professor W. K. FISHER

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MAN'S earliest interest in the sea was probably connected with his stomach, but there is evidence that from very ancient times the ocean has served him equally well in feeding the spirit. It has been an unfailing source of wonder, second only to the stars and the infinity of stellar space, and it has supplied a galaxy of mysteries which will rescue biologists at least from any danger of ennui. Its hordes of queer creatures—the multitudes of sponges, jelly fishes, anemones, corals, sea stars, crabs and other unfamiliar animals—never fail to awaken our curiosity. Our existence, even, is bound up with the sea, for terrestrial life is possible only by reason of the water, which, originally derived from the ocean, falls upon the land and returning in streamlets and rivers repeats the never-ending cycle. More directly we regard it as an inexhaustible source of food, for we take from it enormous supplies of fishes, oysters, clams, crabs, lobsters and fry of lesser value.

The sea subtracts as well as adds. If the cod, herring and halibut yield millions to commerce, the lowly shipworm, a bizarre mollusc, bores unseen into harbor piling and causes wharves and warehouses to collapse by its diabolical industry. New York harbor and other eastern ports are threatened by an attack of this pest, which has already inflicted on San Francisco a property loss estimated at fifteen million dollars. The shipworm or teredo when very tiny enters the wood through a hole hardly bigger than a pin. The bores become rapidly larger as the animal grows, until they reach the size of a leadpencil. Unprotected piles are soon riddled and often the first intimation of the molluscs's presence is the collapse of the wharf or warehouse. The species which is particularly to be feared on the Atlantic coast reproduces at a prodigious rate, is able to live in brackish water and appears able to thrive in harbor water carrying heavy loads of sewage. Where teredos are now established the destruction is so great and the means of protection so expensive that they are responsible for from one fourth to one third of all the costs of loading and unloading vessels at wharves—a bill which, of course, is paid by you and me.

Whether we are concerned with whales, cod or shipworms, any conception of the life and background of these creatures necessitates an appreciation of a fact easily overlooked—that the ocean

consists of salt water. For all the varied properties of water (or rather of a dilute solution of the earth in which common salt predominates) are brought to bear upon every animal and plant, however great or small, that lives within it. Heat, light, oxygen, moisture are no less essential to oceanic than to terrestrial animals and plants. In addition, the ability of tiny organisms to maintain their proper level in the sea is profoundly affected by changes in the density of water, and especially by fluctuations of its internal friction or viscosity, for water is more sticky when cooled just as molasses and other fluids are. To this attribute of water—and the subtle adjustment thereto of the microscopic atomies of the ocean—is linked the welfare of practically all oceanic animals. This leads us to the meadows of the sea and the ultimate source of that organic energy which is the title of this article.

For what, after all, are animals and plants, if not self-sustaining and self-perpetuating expressions of energy? This energy, so physicists suggest, is jarred loose during atomic disturbances within the sun—electron displacements, induced, it is believed, by unthinkable heat and pressure at the core of that fiery maelstrom. Shot inconceivable distances into stellar space, a very small portion of this vagrant energy is picked up by the green vegetation of the earth—by the plants of the land, and their equally important but unseen microscopic prototypes of the sea. In the presence of sunlight, by virtue of this radiant energy, the green coloring material in plants breaks down carbonic acid and, adding water, builds up the sugars and starches, so desperately essential to every animal. In addition, plants use for the maintenance of their basic life-stuff, called protoplasm, simple compounds of nitrogen (previously prepared by bacteria), phosphorus and sulphur, which in the form of nitrates, phosphates and sulphates are dissolved in water and reach the plant by absorption into its tissues.

Animals can not use these relatively simple compounds. They require the highly organized proteids, the sugars, starches and fats, and these can be elaborated from their constituents of the air and soil only by plants. Hence, no plants, no animals. A picture of a world suddenly deprived of vegetation is lugubrious. The plant-eating animals would first perish, followed by their carnivorous enemies. The organic remains would cover the earth and charge its waters, at last falling prey to the denitrifying bacteria until reduced to the inorganic materials of air and soil, when the bacteria would themselves succumb, and the world would be dead.

Energy, then, is stored by plants, and the great reservoir in the ocean is not the conspicuous seaweeds, important as these are, but those inconceivable billions of microscopic diatoms, coccolithophores, dinoflagellates and related forms which collectively com-

prise the ocean meadows. In these floating pastures, sometimes termed plankton, the tiny diatoms with siliceous shells of exquisite form and sculpture comprise the grass. They are so small that only the largest can be seen by sharp eyes. Yet these are giants to the coccolithophores, another group of important and very ancient algae with limy shells. Three to six thousand of the tinier species may lie side by side within an inch.

The newer biology of the ocean is greatly concerned with the distribution of these energy-fixing organisms and their associates of the plankton, for it is this permanent stock of sea-soup which provides food for all the animals economically important to man. They are by no means equally distributed, for the ocean no less than the land has its deserts. Among the diatoms, numerically the most important, there are clearly marked arctic, temperate and torrid zone forms. They are more abundant in cold than in warm seas, and probably owing to a rich supply of organic detritus washed from land, they form a thicker sea-soup near continents than in mid-ocean. Their areas of greatest abundance coincide therefore with valuable fisheries—those of the cod, herring, menhaden, sardine, mackerel, halibut and others which are located in cool or cold water near land.

The transformations which the energy of the sun may undergo between the diatoms, let us say, and the larger animals vary widely in number. The commissary chain may be surprisingly short. The sardine and menhaden feed directly upon diatoms and microscopic, plant-like animals, the dinoflagellates, which are filtered from water, taken into the mouth, by numerous overlapping rows of delicate filaments attached to the gill-arches.

The next link in the chain is furnished by the prodigious swarms of wee shrimp-like copepods, and other minute plant feeders of the animal plankton, which bridge the gap between diatoms and larger creatures, including the young and adults of many fishes. They are the meat of the sea-soup. Sixty thousand have been found in the stomach of a single adult herring, while three thousand were taken from a herring only two and six tenths inches long. Together with minute molluscan pteropods they form the chief food of the huge arctic right whale and the boreal blue whale, which screen out the minute organisms by means of finely fringed plates of "whale-bone"—a device mechanically very similar to that of the sardine and menhaden.

An analysis of this mixed plankton gives some idea of the nutritive values of the organisms. The figures, when reduced to roundness, are in this order: One copepod equals one hundred and twenty-five dinoflagellates (Peridinium) equals two thousand five hundred diatoms. A rich vertical haul through sixty feet of water

taken in Kiel Bay, contained two hundred and seventy-three million diatoms, eleven million six hundred thousand dinoflagellates and ninety-six thousand copepods.

The existence of the microorganisms of the plankton depends upon their ability to keep afloat within reach of solar light, and many are the devices for increasing buoyancy. One of the commonest is the storage of oil, but perhaps the most interesting are those which enlarge their surface, or size of projection, transverse to the direction of sinking. As every one knows, a thin plate sinks faster edgewise than flatwise. Copepods develop feather, plate, or rod-shaped appendages, and many diatoms have suspension organs in the form of hairs or the cells are very much prolonged or are united in linear colonies. Since changes in temperature profoundly modify the buoyancy of tiny organisms, because cold water offers more resistance than warm, many diatoms can adapt their floating forms to seasonal fluctuations. Distinct summer and winter phases are produced, the former having usually thinner cell-walls and a more slender structure. Their excess weight is reduced, though at the same time their surface is comparatively larger. Kofoid has shown that certain dinoflagellates (Ceratium) are able to regulate their floating power, for when they enter colder or warmer layers they can shed portions of their horns or grow longer ones at will. They also have the power of discarding layers from the cell-wall, which normally increases in thickness during the life of the animal.

The conservation of the food supply of fishes is quite as important as measures for the protection of the fish themselves. The latter are not likely to be exterminated by ordinary operations, because these will cease automatically when the fisheries become too depleted to pay; and there will ordinarily remain an abundance of seed stock in inaccessible places. The food question is one of linkage of organisms, the ends of the chain being often as apparently unconnected as the cats and the clover in Darwin's famous story.

The three most prolific sources of fish food are the sea-soup, dead remains in the mud of the ocean floor and the growth of seaweeds and eel-grass along shore. While few fish eat microscopic organisms directly, and still fewer browse on seaweeds or mud, the food chain includes creatures which get their sustenance from these supplies. Steam trawling, where vigorously prosecuted, as in Europe, grazes the very soil of continental plateaus,, ruining bottoms that are fittest for breeding, destroying food and entailing a wastage that Prince Albert of Monaco estimated to exceed fifty per cent. of the edible produce sought. For we must include in this summary valuation the young killed by the drag-net as it passes, and those which reach the ship in such condition that they are useless. Whenever such operations become a menace the logical solu-

tion is the establishment of closed areas. In those parts of the sea where the war prevented fishing for a number of years, plenty of fish are now available, some of a size unheard-of for thirty years. We must, then, guard the sources of fish food. It is distinctly unwise, for example, to pollute our California littoral with crude oil, as has been done for years. Injury is difficult to prove until after the harm is done.

Great advances have been made in recent years in the study of the action of marine organisms upon one another. The general program of the International Committee for the Investigation of the Sea, with its mapping of breeding grounds and the movements of fishes and their young, is a very distinct advance in cooperative work between biologist and oceanographer. Our own Bureau of Fisheries has for years been collecting information concerning the life history of economically important marine animals, to such good purpose that commercial fisheries have profited very many-fold the cost. The North Pacific is still a little known body of water, and we can not use analogies drawn from the Atlantic. It must be explored intensively, for increasing population on its shores will inevitably bring greater demands upon its resources. So far as the United States is concerned, this is the most important immediate task in oceanic biology.

The new world of the deep sea was practically discovered by the Challenger Expedition (1872–1876), which, as Murray remarked, may be ranked as a Columbus voyage in the history of biology. Hitherto the great depths were believed to be lifeless. Now we know that the greatest depths are inhabited.

The average depth of the ocean is two and a half miles. That portion deeper than two miles comprises more than half the superficial area of the earth, or about one hundred millions of square miles. There are many great depressions from three to five miles deep; the greatest, near the Island of Guam, being sixty-six feet less than six miles. The weight of such a mass of water upon the vast, frigid, black realm of the abysses is impossible to sense, for if pressure per square inch increases approximately a pound for every two feet, the ordinary depths of two miles carry considerably over two and a half tons to the inch, and the bottom of the greatest deeps, six to seven and one half tons—certainly pressure enough to account for the soft permeable bodies of abyssal animals.

The sun's heat is lost in the upper layers of the ocean, and by vertical currents reaches a depth of only about nine hundred feet, a mere scratch on the surface. The abysses are intensely and uniformly cold, often near the freezing point of fresh water, and below thirty degrees Fahrenheit in the polar seas. This icy water, rich in oxygen, is chiefly derived from the Antarctic, whence it creeps at

intermediate depths, slowly counter clock-wise, around the great ocean basin, a titanic if feeble whirlpool from whose inner border currents sink into the greatest depths. To a less degree there is a similar flow from the Arctic, possibly drawn into the larger Antarctic current. Interesting confirmation of the southern origin of deep Pacific water has been furnished by A. H. Clark's work on the distribution of certain crinoids or sea lilies. The writer has found similar evidence in several genera of sea stars.

The ability of water to absorb heat rays applies also to other radiant energy from the sun. Light disappears in the upper layers of the sea, the red and orange yellow rays being the first to go, then the green, blue and violet. A Swiss naturalist, Hermann Fol, in a diving suit in the clear waters off Nice, France, observed that at only thirty feet the light disappeared quite suddenly in the afternoon, long before sunset. At one hundred feet, the light was so dim that he could gather animals only with difficulty, and he noticed that dark red animals appeared black. The depth to which light penetrates has been tested by lowering highly sensitive photographic plates. Some work by Bertil and Grein is very exact. If we place as 1000 the amount of light radiation reaching one meter down, at 5 meters there remains but 3.7 of red, 2.5 of orange yellow, 230 of green, 450 of blue, and 866 of violet blue. At 50 meters red rays are reduced to 0.0021; at 100 meters, 0.001 of the orange yellow remains, and at 1000 meters, 0.0003 of green, 0.0001 of blue and 0.003 of violet blue; at 1500 meters, violet blue is reduced to 0.00001.

For practical purposes light does not extend in very clear water much below fifteen hundred feet, and that appreciable to the human eye probably does not exceed two hundred feet. The submarine day decreases very rapidly, with depth. Some experiments at Madeira, in March, indicate for sixty-five feet, eleven hours; for one hundred feet, five hours, and for one hundred and thirty feet, only fifteen minutes, at about two o'clock. This is of interest in connection with the daily vertical migrations of most open-sea animals. Multitudes follow the twilight zone up and down at evening and morning, while others, rising only at night from the deeper intermediate regions to within a hundred and fifty feet of the surface, spend their lives in a perpetual vertical oscillation, the period of which is twenty-four hours. These creatures, often uncanny in appearance and scintillating with lights, know neither the top nor the bottom of the sea, and are adapted to withstand enormous variations of water pressure.

Monotony is strikingly characteristic of the eerie deeps, which well-nigh all types of marine animals, from microscopic forms to fishes, have made their abode. There are no seasons—uniform

winter, endless night. Yet with a perfectly uncanny adaptability, protoplasm flows as serenely in temperatures sometimes below the freezing point of fresh water as in limpid pools of tropic reefs. There are no bacteria and no living green plants. A ceaseless drizzle of small organisms that have succumbed in the ocean meadows (perhaps miles above) slowly settles like gentle snow on the ocean floor and provides food for multitudes, which in turn fall prey to others, in thousands of nutritive cycles.

Deep-sea animals are much more delicately constructed than their shallower water relatives, many having bodies thoroughly permeable to water. Glass sponges of exquisite delicacy live successfully under pressure of many tons to the inch, because the whole body is open to the water. Sedentary forms, such as frail, phosphorescent sea pens, arborescent polyps and tall sea lilies or crinoids, rear themselves above the mud, while quaint spiny crabs, with spindly legs and egg-shell bodies, vie in slimness with the pycnogonids, grotesque "all-legs," neither spiders nor crustaceans. In the branches of these miniature forests of tree-animals dwell thousands of different species of all sorts of types. On and within the ooze are other myriads—bristling sea urchins and sea stars, sea cucumbers, inconceivably delicate shrimps, molluscs and worms. Prowling fish, of unconventional design and voracious appetite, feed upon this abundant fauna.

When we ascend a great mountain the vegetation and animals change with increasing altitudes. Broad belts of approximately equal temperature have a uniform assemblage of plants and animals. So it is when with the long arm of the dredge we follow the bottom into deep water. The lighted zone along shore teems with life unlike that at one hundred fathoms, while at five hundred fathoms still another world is seen, and so on with increasing depth. That temperature is the most important factor seems likely, for at five hundred to one thousand fathoms off California are found relatively shallow-water subarctic types.

Our knowledge of abyssal animals really began with the *Challenger* Expedition under Wyville Thompson. From 1872 to 1876 this vessel covered sixty-eight thousand, nine hundred nautical miles and brought home results which have required forty huge volumes to record. Then came the American *Blake,* under Agassiz and Sigsbee, followed in 1883 by the fisheries steamer *Albatross,* whose many cruises, to mention only the Pacific, have extended from Bering Sea to Cape Horn, Polynesia, the East Indies and Japan. The care of her enormous collections has been one of the many duties of the National Museum, ably executed under financial handicaps, and to the cooperation of specialists we owe the high

place which this country now holds in the development of marine biology.

Europe has been very active, nearly every maritime country taking part. The late Prince Albert of Monaco devoted thirty-seven years to submarine exploration, first with the *Hirondelle,* and since 1898 with the second *Princesse Alice.* To him is due much of our knowledge of the great intermediate depths. He founded the Oceanographic Institute at Paris and the Oceanographic Museum at Monaco. Carved in large letters on the frieze of this building are the names of all the more important vessels which have contributed to the science of the sea—*Albatross, Blake, Gazelle, Investigator, Novara, Vitiaz, Belgica, Talisman, Valdivia, Washington, Vega, Fram, Princesse Alice, Hirondelle, Pola, Challenger, Buccaneer, Aurelia* and *Ingolf.* To these should be added the recent Norwegian ship, *Michael Sars,* which has done splendid work in the North Atlantic.

The production of light by animals has always possessed a peculiar fascination for humans, and it is one of the problems of the deep sea. It is exhibited by creatures of all scales of complexity, by sedentary forms and by swimmers. In the wide, lightless reaches far above bottom we meet that vertically oscillating fauna, which as regards the fishes and cuttlefishes, is characteristically luminous. Clearly defined and localized light-organs of glandular origin sometimes possess a lens and reflector, and occur in queer places, inside the gill-cavity, on the end of the tail, or on the eyeball of devilfishes. There they emit an ultramarine, clear blue, pearly white, greenish or ruby light. The tiny lanterns are scattered, or gleam in straight rows along the sides, like illuminated portholes of a fairy ship. In bottom animals, luminosity is associated more often with surface slime than with localized organs, being caused, as in most other cases, by oxidation of a special compound.

Does animal light afford a dim glow in the abysses? Why does the cuttlefish illuminate its gill-cavity? Why in certain others is the disposition of luminescent organs different in the two sexes? Why does the angler have a lighted bait on his rod? The best we can do is to guess; but if light is useless, why do many abyssal fishes, cuttlefishes and crustaceans have well-developed eyes? What shall we say of the microscopic Noctiluca, dinoflagellates and tiny crustacea which coruscate and gleam in the ocean meadows so brightly that they guide fishermen to feeding shoals? And not only adult animals but larvae, embryos and even eggs are known to be luminescent.

If we are in search of underlying purpose, a wealth of mystification will follow even a cursory examination of the rich reds, oranges, yellows, brown-purples and purple-blacks that predomi-

nate in the colors of the abyssal population, most of which are untouched by the ghost of a solar ray. In the squashy, frigid ooze, a mile or more down, dwell gorgeous red and purplish sea pens, orange, rose and violet sea cucumbers, yellow, orange, red or purplish sea lilies, rose, red and salmon sea stars and crabs, purple-brown fishes. Far above them, at various levels in the black 'twixt world swim curious chocolate and red jellyfishes, black fishes with an extraordinary dental equipment, mirror-sided, goggle-eyed fishes, glass-clear ellarvae, blazing red shrimps and a host of colorful cuttlefishes twinkling with lights.

In contrast to these heavy tints are the delicate colors or lack of color of animals living at or near the surface. Every sailor is familiar with the sea-blue peculiar to many surface forms, especially in the tropics. Fishes are likely to have silvery sides, and dark bluish or olive backs. Lovely blues and violets characterize jellyfishes, Portuguese men-o'-war and numerous unrelated animals. Others are transparent, as the exquisitely delicate ctenophores or sea gooseberries, which move languidly beneath the surface and devour enormous numbers of tiny cod. The diaphanous young of multitudes of creatures dwell in the intermediate depths and approach the surface only at night. The leptocephalus larva of the common eel is transparent except for its tiny black eyes.

In the whole realm of marine life there are probably no more baffling problems than those connected with the migration of fishes. As is well known, salmon ascend rivers to spawn. The exact researches of C. H. Gilbert have demonstrated that the sock-eye salmon revisits not alone its natal river system, but the particular tributary of the river in which it was hatched. In some cases he has found that they return to the ancestral spawning bed. The young fish put to sea when upward of eighteen months old, and lead an oceanic existence for three or four years. On the return journey, after finding their river, what guides them so unerringly to their old home? Temperature has been invoked by Ward.[1] Let us examine the facts. As the salmon ascend the stream and reach the first spawning tributary all of them, though perhaps in varying degree dependent on their position in the stream, are exposed to the influences of the inflowing tributary as well as to the sum total of the environment at that point in the river. Yet some respond by turning into the tributary, while the rest go on: and those that enter the tributary are the ones that were spawned there. The same scene is enacted at the next spawning tributary and the next. Ordinarily, colder waters enter with the tributary, but if tempera-

[1] "Some of the factors controlling the migration and spawning of the Alaska red salmon," *Ecology*, II, 1921, 256.

ture is the guiding star of their existence, why do those who were not spawned in that particular affluent refuse to respond to the temperature stimulus? If their "homing instinct" dominates temperature stimulus in these cases, why infer that temperature is ever a controlling factor?

If we fall back upon memory, how shall we explain the dramatic odyssey of the river eel, traced by Johannes Schmidt of Copenhagen? In the autumn fully mature eels descend rivers and put out to sea on their first and only spawning migration. They swim prodigious distances. Those from the Baltic streams must work past Denmark and the British Isles. They then turn southward and disappear. It is now known, from a study of their queer ribbon-like larvae, that most of them cross the Atlantic to a region southwest of Bermuda, also frequented by the distinct American eel. The reason they vanish soon after leaving continental shores is because they spawn in the intermediate abysses, about three thousand feet down, and then die, as do the salmon after spawning. The transparent larvae, in size and shape much like a small willow leaf, dwell in this intermediate region, making nightly excursions to near the surface, where they associate with their American relatives, whose parents have made a somewhat shorter journey from the rivers of North America.

When the young become a little over an inch long, the two species separate. One starts for America, the other for Europe, to which the journey consumes about a year. First they grow to be from two to three inches long, but afterwards gradually shrink as they become slenderer until when near shore they are tiny eels. In the spring they ascend rivers, the females for the most part proceeding to headwaters, while the males remain near or in tide-water. Here they live for five or more years before starting on that strange journey into the mid-Atlantic abysses from which they never return. What guides the adults to the spawning places? Why do American and European larvae sort out, one turning to the left, the other to the right, with seemingly nothing to guide them through the vast dark spaces to their future home? We simply do not know. But of one thing we are certain: These and a multitude of similar problems will always give zest to the study of marine life and will free it from any risk of becoming monotonous.

RETAINING WALLS

By Dr. JACOB FELD

Something there is that doesn't love a wall,
That sends the frozen-ground-swell under it,
And spills the upper boulders in the sun,
And makes gaps even two can pass abreast.
—Robert Frost: "North of Boston."

THE search for this something is an old problem in engineering research, and after building walls for several thousand years, we are just about beginning to get an idea of what this "something" really is. Walls have had a habit of failing, refusing to stay where put, more so probably than any other type of structure. The ancient Babylonians tried to solve the problem by a law which fixed a penalty for constructing walls that would not stand:

Summa banum bitam ana awilium ibuus ma sibi irsu la-uste isbi ma igarum iktuup banum su-u ina kas pim b'ramanisu igarum su-ati udanna-an. —From the Code of Hammurabi, 2200 B. C.

The Harper translation of the Code of Hammurabi reads:

If a builder build a house for a man and do not make its construction meet the requirements and a wall fall in, that builder shall strengthen the wall at his own expense.

The Romans built many revetments, fortification walls for the protection of their camps. Some of these walls have withstood the ravages of the natural elements as well as the man-made agencies of destruction. But the walls are so heavy and over-safe that the cost of such construction at this time is prohibitive. The problem passed on to the French military engineers of the 17th and 18th centuries, and it was with them that the idea of an experimental study of the action of soils originated.

At first it was thought that soils should be classed as liquids; but they act in a somewhat different manner. While a liquid will transmit pressure in all directions undiminished and will always act perpendicular to the surface which retains it, it is known that a material like sand will not transmit pressure undiminished, and the effect is not perpendicular to the wall. This is the reason for the use of gravel or crushed rock as a shock absorber, as in railroad track ballast, floors carrying heavy or vibrating machines or trucking, etc.

Such materials, often classed as granular, have more recently

been considered as solids in a divided state. But the very idea of division prohibits this classification. The deformation of the solid state, in which matter has a constant shape and a constant volume, implies the property of elasticity. As a matter of fact, the criterion for the solid state is the obedience of Hooke's law, "Ut tensio sic vis"; the deformation is directly proportional to the force acting. This law does not hold in granular materials for compressive forces, and such materials have practically no tensile strength.

It was to obtain a little more information about the action of soils, especially as applied to the design of retaining walls, that the University of Cincinnati built a large apparatus to test the lateral pressure of granular materials. The design was based upon the most successful apparatus of the past, that of Dr. Heinrich Mueller-Breslau of the Charlottenburg Laboratories in Germany. The Cincinnati apparatus is, however, much larger and simpler in construction, yet it is the most accurate device ever made for this purpose.

It consists of a large concrete box, five feet wide, nine feet long, six feet high in the front and twelve at the rear. The front side, five by six feet, is left open and a wooden wall fits into the opening; the wall is not connected rigidly to any support but rests on two large platform scales. There are three horizontal rods situated so that the wall bears against them if moved away from the bin, one at the top in the middle and the other two at the lower corners. When the earth is shovelled into the bin, it exerts a pressure against the wall. The vertical effect is measured directly on the two scales, the horizontal push is against the three horizontal struts which are connected to bell cranks, elbow shaped levers, which transmit the pressures vertically onto the other three scales. In this way the effect of the earth in both directions is measured directly by platform scales, the simplest device possible for reading pressures.

It would not do to allow the wall to move appreciable distances. For then the grains in the earth or sand behind the wall would have an opportunity to change their relative positions, thereby influencing the acting pressure. By careful control, readings were obtained while the wall was restrained from moving more than 1/8000 inch vertically and 1/16000 inch horizontally. Such small distances are, of course, not visible and not easy to measure directly. By the use of levers, including those inside the scales, the distances were magnified 800 times.

Some valuable results were obtained with this apparatus. Unlike fluids, it was found that the pressure of soils was always oblique to the wall. To absolutely determine this result, the tests were repeated with glass and sheet metal backings on the test-wall. The

inclination for each type was different but it was a constant in all the tests with the same wall. It was found that this constant was the coefficient of friction of the filling material on the wall.

This coefficient may be found from a very simple experiment. If a bottomless box (a chalk box with the bottom removed was used) is filled with sand and weighed, then placed upon a horizontal sheet of glass and by means of a spring scale the force required to move the box is determined, the ratio of this force to the weight of the sand is the coefficient of friction between sand and glass. Likewise for other materials. To eliminate the contact between the sides of the wood box and the glass, the bottom ends of the sides are bevelled to an edge so that, practically, the only contact is between sand and glass. The results of the large experiments then indicate that the effect of settling as the earth is placed back of a wall is to bring into play the friction on the back of the wall. A curious result found was that the friction of sand on glass was greater than on sheet metal. The same conclusion was drawn by Mueller-Breslau in 1906.

To find out how great the force exerted by the earth is, the experiments show that the so-called theory of the "wedge of maximum pressure" very closely approximates the actual conditions. Earth in a natural condition will assume a fixed slope to the horizontal. This is characteristic of every soil and is noticeable in the slopes of hills and mountains as well as in the smaller piles of sand or sugar which are usually seen. If a wall is put up and a material shovelled behind it, that part of the fill above this plane of "natural slope" tends to slip down. Such slip is prevented by the action of the wall as well as the friction along the natural slope. The theory of the wedge of maximum pressure assumes that not all of this material acts against the wall, because of the friction on the natural slope, and determines what portion should act in order that the pressure against the wall be a maximum. This theory was first announced in 1773 by Coulomb who also made such wonderful contributions to the other sciences, chiefly electricity.

One of the new features studied in these experiments was the effect of age and temperature on soil fillings behind a wall. One test consisted of watching a fill of wet sand for eight days, taking readings of the pressure and temperature at all hours of the day and night. It was found that the pressure against a wall is a maximum directly after the fill is put into place. It remains at this value, sometimes increasing slightly, for a few hours, but within 24 hours, some internal settlement or binding has caused the pressure to drop by sometimes over ten per cent. of the original value. The pressure then increases again, varying with the temperature. Each day, the highest pressure occurred at about 2 P. M., the lowest at

FROM THE CODE OF LAWS OF HAMMURABI (2200 BC) KING OF BABYLONIA

A If a builder build a house for a man and do not make its construction firm and the house which he has built collapse and cause the death of the owner of the house – that builder shall be put to death

B If it cause the death of the son of the owner of the house – they shall put to death a son of that builder

C If it cause the death of a slave of the owner of the house – he shall give to the owner of the house a slave of equal value.

D. If it destroy property, he shall restore whatever it destroyed, and because he did not make the house which he built firm and it collapsed, he shall rebuild the house which collapsed at his own expense.

E. If a builder build a house for a man and do not make its construction meet the requirements and a wall fall in, that builder shall strengthen the wall at his own expense

Translated by R F Harper
"Code of Hammurabi" p 83 - seq

Jacob Feld 1922.

about 4 or 5 A. M. The amount of variation throughout the day decreased as the age of the fill increased; the curve showing the variation of pressure with age is very similar to the usual "damped vibration" curve, such as the vibration of a violin string or a spring.

The usual trouble in walls is the effect of surcharge loads on top of the earth. To determine their effect, kegs of nails, weighing 100 pounds each, were placed at various points on top of the fill and the effect measured. Loads off the theoretical wedge of earth which will exert the maximum pressure seemed to have but little effect on the pressure, while loads near the wall increased the overturning effect considerably. Similar kegs of nails were rolled across the fill and showed an increase in pressure. The remarkable point was that, after the loads were removed, the pressure did not diminish immediately. Loading seems to compress the earth, which remains in this state for several days, before it comes back to its original state.

Working with soils is a very tedious but interesting study. Small apparatus is practically worthless, for earth is not uniform and large quantities must be used to obtain reliable results. This is one reason why the research in soils has lagged behind the advances in the other branches of applied science. The tests described here required shovelling about 300 tons of material by hand. Hand shovelling is much more easily controlled with consequent greater accuracy and safety of the apparatus. A complete report will be found in the Proceedings of the American Society of Civil Engineers, April, 1923.

It will take numerous hundred more tons of shovelling before we can completely answer the question in the same poem by Robert Frost:

> Before I'd build a wall I'd ask to know
> What I was walling in or walling out,
> And to whom I was like to give offense.
> Something there is that doesn't love a wall,
> That wants it down.

THE CULTURE-PEARL FISHERY OF JAPAN

By Dr. DAVID STARR JORDAN
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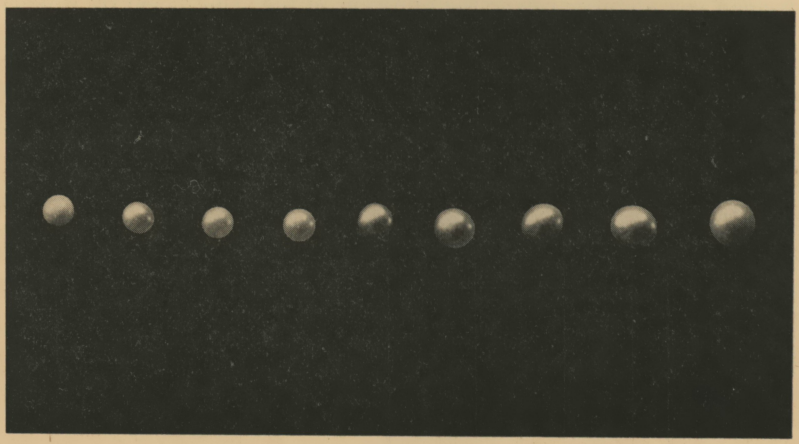
In the south-middle part of the main island of Japan lies the large peninsula of Yamato, very mountainous and very picturesque, one of the early homes of the Yamato race, which, whatever its origin, now dominates Japan. On the east side of this area, stretching along the shore of the bay of Ise, lies the province of Ise, with the large seaport towns of Tsu and Yamada, the latter world-famous for its forest-embowered Shinto shrines, to which every pious Japanese who is not a Buddhist is supposed to make a pilgrimage every year. Just south of Ise lies the diminutive province of Shima, made up of delightful peninsulas, islands and intervening bays, suggesting a fragment of Greece but with very different human surroundings. Its chief town is the little fishing city of Toba, and twenty miles south of Toba is the unique Mikimoto Pearl Oyster farm.

The writer was in Yamada in November, 1922, in company of Senzi Yamamoto, lecturer on genetics in the Imperial University of Kyoto, who helped him to complete his large collection of Japanese fishes. While there we received an invitation from Kokichi Mikimoto to visit his pearl farm, his automobile being sent to meet us at Toba. We left Toba on one of the rare perfect days which come to Japan in November only and even then but seldom. The air was



MIKIMOTO'S CULTURE PEARLS
Taken from nine pearl oysters (slightly enlarged); November, 1922.

Kokichi Mikimoto

free from mist and the outlines of the mountains of Yamato and of the barren sandstone islands of Shima were as clear cut as in the most atmospherically favored lands. After fifteen miles of narrow roads, across hill and valley, intersected by clear streams and forests ablaze with maples, the

> Brown rocks weathering
> 'Neath their bamboo feathering

we reached Ago Bay.

Here Mikimoto met us with what was literally a steam tub, an open boat almost as wide as long with high bulwarks and no deck, its inside fitted with easy chairs. It was propelled by a little engine in front, adequate for the few miles of water between the shore and the sandstone island of Tatoku, the seat of Mikimoto's operations.

It has long been known that a species of Pearl Oyster (*Margaritifera martensi*) inhabits the waters of parts of Southern Japan. It is a small species, much less robust than the "Panama" oyster of the Gulf of California (*Margaritifera mazatlana*) and the west coast of Mexico.

The channels and inlets of Southern Shima (Shimei-ura) are unique in the clean sandstone bottom and in the entire absence of tributary fresh waters, while open to the warm wash of the Kuro Shiwo (Black Current), the "Gulf Stream," which sweeps northward from the Philippines and Formosa.

The Japanese people cared little for pearls (*shinju*) or other jewels, but they have found a ready foreign market for the relatively few gathered by the pearl-divers of Shima, who used to bring them in along with abalone (*awabi*) and agar-agar (*Gelidium*), a sea weed largely used in medicine.

In pearl fishing, Kokichi Mikimoto became early interested. He was born in Toba in 1858 and it is said that in his modest boyhood days he used to peddle about the town the Japanese equivalent to macaroni. It is well known that the pearl is secreted, layer by layer, from the mantle or soft envelope of the pearl oyster to cover a form of irritation, usually that of some parasitic worm, a fluke (Cestode) or the larva of a tapeworm. In the early nineties, Dr. Kokichi Mitsukuri, dean of the College of Science in the Imperial University of Tokyo, most distinguished of Japanese men of science, suggested to Mikimoto the possibility of producing pearls by artificial irritation. This idea was carried into practice by Professor Isao Iijima, and Mikimoto, aided by his clever son-in-law, Dr. Nishigawa, undertook in 1880 the bold plan of pearl-farming on a great scale, a large and costly venture demanding great initial faith, the first harvest being marketed eight years later.

PEARL DIVERS AT TATOKU ISLAND

Leasing the picturesque island of Tatoku as a base of operations, he secured the rights to about fifty miles of the bays around it. A portion of this area is given to the spat or young oysters. Small stones are scattered over the bottom and to these the newly hatched fasten themselves by a byssus or set of threads. These are left to grow for about three years. They are then gathered and under the mantle of each one is introduced a small round fragment of oyster shell (mother of pearl). These are then transferred to the south side of Tatoku Island into water so deep (thirty to forty feet) as to prevent all danger of freezing. The animals are "planted" about a foot apart and held for some five years more, when they are brought up by the divers, nearly every one having then a pearl of some value, the market price of these "culture pearls" (*Yoshoku Shinju,* "pearls for foreign taste") ranging usually from $200 downward, according to their size, form and purity. As they are of exactly the same substance and color as the natural or "uncultured" pearl, there is no real reason why they should not have the same value. The culture pearl is formed about an irritating bit of mother-of-pearl; the other is the sarcophagus "of a worm untimely dead." Each sort has the same luster and sheen, a quality which cannot be imitated by any form of "paste" or artificial pearls. The chief drawback, a tendency to flatness on one side of the culture pearls, has been largely overcome.

The best methods of irritating the pearl oyster have been carefully studied, and patents of this process have been taken by Miki-

moto. Following his methods several other pearl farms have been established in similar waters elsewhere in Southern Japan. The output of the Mikimoto farm for 1921 amounted to about 1,200,000 yen ($600,000). The total yield from Japan now approaches $5,000,000 yearly.

The pearl divers (*ama*) at Tatoku form an interesting group. These are all young women from eighteen to thirty-five years of age, vigorous and muscular. It is said that the profession has become hereditary in the province of Shima. Women are preferred to men for this work, as it is claimed that they can stay under water longer (two to three minutes). Their husbands find employment in taking care of the shells and pearls and in other duties about the island. Mikimoto's divers wear cotton suits not unlike pajamas, white cotton caps, and a large water glass for better vision. Each one as she dives from the boat has with her a floating tub in which to deposit her clutch. In the interval between plunges the divers kept up a sharp whistling, a process which is said to give them lung-strength for their work.

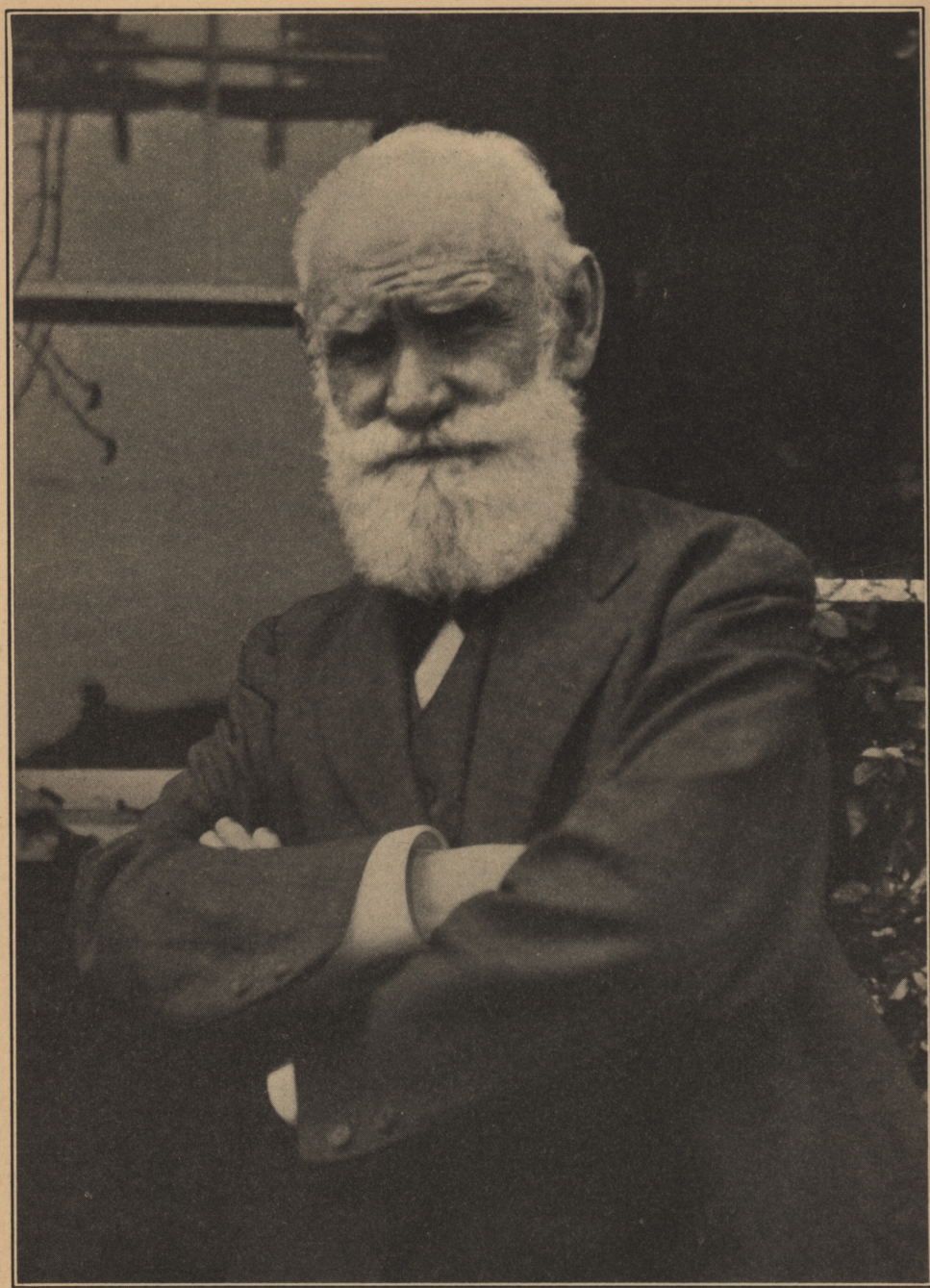
The salt water tends to coarsen the skin and to redden the hair, but the women seemed unusually robust and in their way not unattractive. Like all other Japanese, they are endlessly good natured, and when we left the island, after they were back in kimono and obi, they said *Sayonara* (good-bye) in the friendliest fashion, waving their handkerchiefs until we were out of sight. These women are in their way aristocrats among divers, unlike the red-skirted,

SORTING THE CULTURE PEARLS AT TATOKU ISLAND

naked-shouldered water-sprites who gather abalones (*Haliotis*), locally known as *awabi* and agar-agar (*Gelidium*) off Toba, Matsushima and many other places in Japan.

The rearing of pearl-oysters (*kaki*) is not without its difficulties. Star-fishes sometimes invade the beds, thrusting their protrusible stomachs into the opened shell and then digesting out the animal. Carnivorous sea-snails attack the oysters and boring worms and mollusks do their share of mischief. Sting-rays are often destructive as on ordinary oyster beds. The growth of certain sea weeds sometimes chokes the young animal. Worst of all an invasion of a type of minute organisms from the Kuro Shiwo occurs at times. These creatures constitute the dreaded *Akashiwo* or red current, fatal to these mollusks.

The harvest season for pearls is in early December, but Mikimoto sent out for our edification nine of the divers, each one bringing in a pearl oyster. Opening these in his summer house on the hill, a pearl was found in each one. Two of the oysters were fried for my luncheon and in one of these (very delicious by the way) I found a minute natural pearl. Our visit ended, Mikimoto gave the whole pearl catch of the day as a present to Mrs. Jordan, a friendly souvenir of a delightful and instructive visit.



IVAN PETROVIC PAWLOW

The distinguished physiologist of the University of Petrograd. Photographed at Wood's Hole by Julian P. Scott, when Professor Pawlow lectured there at the beginning of July.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

COPPER IN COMMON LIFE

EVERYONE knows copper, however little he may know about it. The first object to attract his infant eye was very likely the brass knob of a bed or door. He early learned the monetary value of the metal by finding that it was legal tender for saccharine delights at the candy shop or slot machine.

So also in the childhood of the race was copper the first known of the useful metals. Some savage scientist, unknown to fame, picked up a piece of jagged red rock that seemed more serviceable as a knife than the familiar flake of flint. But when he tried to sharpen the edge with a stone hammer he found that instead of chipping off in little shell-shaped scales the strange material gave way beneath the hammer blows without breaking and so could be beaten into any desired form.

We may imagine the pride with which the pre-historic inventor exhibited his new-fangled knife or spear-head to his tribesmen, but we may also surmise that they laughed at him for carrying around such a queer contraption, and that when he demonstrated its superiority over flint he was robbed of his invention by some less original but stronger warrior. For we can not imagine that troglodyte society was so superior to ours that an inventor would meet any better fate than he does nowadays.

Comparatively few people know how beautiful copper is because comparatively few people have ever seen it. What most have seen is but the painted face of copper, the mask it puts on when exposed. To see the metal as it really is one must strip it of its concealing coat by heating it to redness in a glass tube through which hot hydrogen gas is streaming. Then the copper is revealed as a shining silvery metal, delicately tinted with pink like the inner petals of a rose, less garish than gold, less steely than platinum.

But draw the copper from the closed tube and let a breath of air strike it and instantly a blush spreads over its face, deepening to a red, as a baby's skin burns in the seaside sun. This soon darkens to a dull bronze, and further action of the air and moisture gives it a greenish or bluish tint. This fine patina is highly esteemed by artists and antiquarians on roofs and statues, but our municipal authorities call it "verdigris" and scratch it off occasionally with a sand-blast. They had better leave it on for both esthetic and economic reasons, for the bare metal can not stand exposure and no paint is more protective than this that is made by the very atmospheric agencies against which protection is sought. Copper coins and castings, coated with the patina, are preserved intact for thousands of years though buried in damp soil where iron implements would soon vanish in a heap of rust.

The readiness with which copper forms affinities with various elements gave it the name of "the meretricious metal," as the alchemists called it. But this very versatility has its value for human needs, for copper in combination assumes many beautiful and useful forms. The greens and

blues of malachite and azurite are gorgeous as any gems, yet they may be had in masses large enough to make tabletops and mantel-pieces. Glass and pottery get various tints from traces of copper, and "blue vitriol" is equally familiar to the electrician and the horticulturist.

Copper is a good mixer and enlarges its field of usefulness by alliances with other metals. Tin gives it the hardness of bronze. Zinc gives it the golden glitter of brass. With nickel and zinc it makes a passable silver. With aluminum, which man has lately learned to extract from common clay, it forms new and useful alloys. The noble metals, gold and silver, in their proudest capacity as coins and jewelry gain strength by alliance with the more plebeian copper.

Copper gets its name from the fairest of the goddesses who chose it as the metal of her mirror. This was, it must be confessed, "Hobson's choice," for Venus is older than she looks and when she rose from the sea, somewhere off the island of Cyprus, her first request was for a looking-glass that she might see for herself the reason for the admiration she perceived in all men's eyes. She was not content like Narcissus with the pallid reflection of a pool, which besides could not be carried around with her, so she sought for a suitable metal. There were only two known at the time, gold and copper. Gold she rejected; not, we must assume, on the ground of expense, for Venus has never lacked admirers eager to pay for her luxuries, but probably because gold cast a sallow tinge on her countenance while copper brightened the tint of her auburn locks and endowed her cheeks with a blush like that of modest maidens.

Anyhow, the handglass of the Cyprian Aphrodite became the symbol of her sex and is still to be found as such in our modern manuals of botany and zoology. The "cyprium" from the Cyprian isle became the "cuprum" of the Romans and the "copper" of the English, and the metal from which was fashioned the jewelry of goddesses and queens was made into pots and pans and the cheapest of coins. A copper button that was proudly worn by a Pharaoh of 4400 B. C. has been found in an Egyptian tomb but it is not nearly so elegant as the buttons that the elevator boy lavishly displays on his uniform.

"Not worth a copper" is the nadir of value yet copper is worth much to the world and never more than in this age of electricity.

THE LIONESS AND THE HARE

Once upon a time, many years ago, a hare boasted of her large family to a lioness. The lioness admitted her quantitative deficiency but added that her one offspring was a lion. It was a conclusive retort—at the time. The lioness had no need to be disquieted by the success of her rival in maternity; indeed, she could rejoice in it, for there was no danger that the hares, however numerous, would crowd out the lions; on the contrary, if there were more hares, there would be more lions and better fed.

Now, however, conditions have so changed that the reply of the lioness is no longer satisfactory. We have put a stop to killing as a factor in the struggle for existence. The lion has his claws trimmed and his jaws muzzled by law. The battle is not to the strong, but the race is to the swift-breeder. The lion and the hare are compelled to live peaceably together and are placed on an equality. Questions are decided by counting noses, not by matching muscles or weighing brains. There is no reason to think that the propaganda of Neo-Malthusianism will ever influence the hares,

nor that any legislative bonus will increase the size of leonine families. Consequently lions are becoming extinct and hares are multiplying all over the earth.

In its modern form, therefore, this fable teaches that the hares are bound to beat the lions in the long run, no matter how much bigger the latter may be or how much louder they can roar.

And having extracted this lesson of eugenics from the fable, drop it right here. A fable is a single-barreled weapon and if you attempt to get more than one shot out of it it is likely to explode, to the injury of the user. So I am not going to discuss whether the savage and predatory lion is a nobler beast than the meek and vegetarian hare and better fitted to populate the world. Still less am I going to identify with the lion and the hare any particular classes or races.

WHAT DID YOU SEE IN THE ECLIPSE?

An eclipse of the sun is one of the few scientific events in which everybody must take an interest. It absorbs the attention of the astronomers of the world, and it does not pass unnoticed by chick or child within the path of totality. It is not now viewed with alarm as in former ages nor held to presage the fall of kings, for both astrology and kings are now generally recognized as exploded fallacies. But an eclipse remains as awe-inspiring a spectacle as ever, and is more fascinating to watch than when it was shrouded with superstition.

We are used to seeing total eclipses of the sun by the earth, for they occur to us every evening everywhere, but a man is rarely lucky if a total eclipse of the sun by the moon comes his way once in a lifetime. The eclipse of September 10 was total only for a strip of the southern coast of California, but the sun was seen as half or more obscured over the entire United States some time between the beginning of the eclipse at 11.15 A. M. in Washington state and its ending at 5.50 P. M. in Florida.

Since the moon has no atmosphere the edge of its shadow is sharply defined, and it can not "overcome us like a summer cloud without our special wonder." To those who are on a high mountain or in an airplane in the path of totality the advancing shadow seems to sweep over the landscape as a wall of darkness, advancing at the rate of a mile in two seconds.

Did you look for the mysterious "shadow bands" that flicker over white walls or other smooth surfaces a few minutes before and after the eclipse is total? They appeared as a swiftly moving series of wavy dark lines, an inch or more wide and a foot or less apart. How fast did they move? Faster than you could run?

Possibly you caught sight of "Baily's beads" named after the British astronomer who in the eclipse of May 15, 1835, observed that the last slender line of light broke up into a chain of dark beads just before the sun was covered by the moon's disk. What color was the last strip? Crimson, yellow or brick red? Bright red protuberances might have been discerned about the darkened disk; "a box of ebony garnished with rubies" somebody has called it. These are jets of incandescent hydrogen ejected from the sun, sometimes a hundred thousand miles into space.

When the sun was quite covered you may have seen the halo or corona which was the chief point of scientific interest in the eclipse. It varies greatly in size and appearance with the state of activity in the solar atmosphere at the time. Sometimes it resembles the cross of light that you

MAP OF THE WORLD ON MERCATOR'S PROJECTION

Showing the regions of the greatest earthquakes and volcanic activity, which are also the regions of greatest earthquake danger.

see about the moon as you look at it through a wire window screen. How far out did the streamers extend as compared with the diameter of the sun's disk? In what direction did they run? Were they symmetrically arranged about the sun or did they reach out farther on one side than the other? Could you draw a picture of the corona as you saw it to compare with the photographs taken by the big telescopes? Was it dark enough to see stars? How many?

But you may have found it more interesting to watch the earth than the sun. Even those at a distance from the region of totality could observe and photograph the curious crescent-shaped flecks of light that appeared in the shadows of trees. How dark did it get? Could you read? Tell time by your watch? Indoors or out? Did it get colder? What did the thermometer say about it? Did a wind start up? As the eclipse became total did the clouds seem to come closer and take on iridescent hues? How did the faces of your friends look?

Did you watch the dog and the cat? Did the birds become quiet and go to roost? Did any flowers close their petals or sensitive plants their leaves? They say that during a total eclipse grasshoppers take a nap while ants keep on working. This is what we should expect from their characters in the fable, but do they?

There was plenty to keep one busy during the two hours or so that the eclipse was on and especially during the two minutes or so that it was total.

THE GEOGRAPHY OF TOKYO

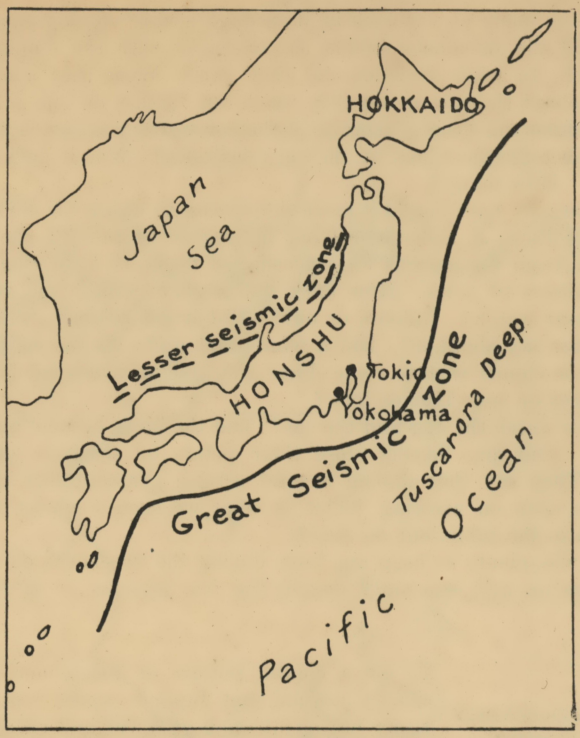
To get a mental picture of Tokyo one must hold clearly in mind that Japan's capital was not really a city but a collection of towns and villages, grown together, the National Geographic Society's news service writes from Washington. These settlements preserved their entity in the fifteen "wards" so frequently mentioned in recent dispatches.

In strolling through old Tokyo, and seeing the frail bamboo and cardboard houses, one could not help considering that the introduction of western buildings greatly enhanced the danger from earthquakes—a speculation now so sadly confirmed.

For the fragile houses might be burned and often were, but could not maim their occupants under piles of mortar and stone. Fireproof warehouses were provided for groups of such buildings and when the alarm of fire was sounded the occupants carried off their valuables to these storage places. A proverb had it "Fire is the blossom of Yedo"—using the older name of Tokyo which was abandoned when the Mikado took up his residence there in 1869.

Japan has had her troubles from volcanoes as well as from earthquakes. For reasons that geologists believe to be inherent in the very constitution of the globe, volcanoes have draped themselves in surprisingly regular festoons—like a chain of pearls caught up at intervals—down the whole Pacific coast of Asia. And of these crescent shaped strings of fire-mountains, the main island of Japan, Honshu, itself a crescent, forms the very center.

The northernmost of the volcanic crescents even touches America, since it is composed of the Aleutian Islands, stretching from Alaska to Kamchatka. The second festoon curves from Kamchatka through the Kurile Islands to northern Japan.



MAP OF JAPAN

Showing the zone in the deeps of the Pacific from which most of the great earthquakes emanate and a zone of lesser activity in the Japan Sea.

Then comes Honshu, the island on which Tokyo and Yokohama are situated. Those ill-fated cities lie at almost the extreme bulge of the central volcanic crescent where the island bends into the Pacific toward a very deep depression, extending perhaps 18,000 feet below sea-level. This great "trench" beside Honshu's foundation, may itself have placed the island in a rather weak structural position.

South of the central Honshu crescent there are two other well defined volcanic festoons, one through the Lu Chu Islands to Formosa; and another from Formosa through the Philippines and Borneo into the great volcanic complex of the East Indies.

On Japan's main island, which has approximately the area of Great Britain, there are a dozen volcanoes that may be considered active and a greater number that are inactive. The closest and most important of the volcanoes near Tokyo are the famous and beautiful Fujiyama, sixty miles to the southwest, which has not erupted since 1707; and Asama, ninety miles to the northwest, which constantly sends up a thin wisp of smoke, and now and then breaks out into a vigorous eruption.

Tokyo has had three particular furies of her own to harry her over and over again; pestilence, fire and earthquake. From the close of the sixteenth century, when the old fishing village of Yedo blossomed into a city at the order of the ruling Shogun, to the present disaster, these three have from time to time taken heavy toll.

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